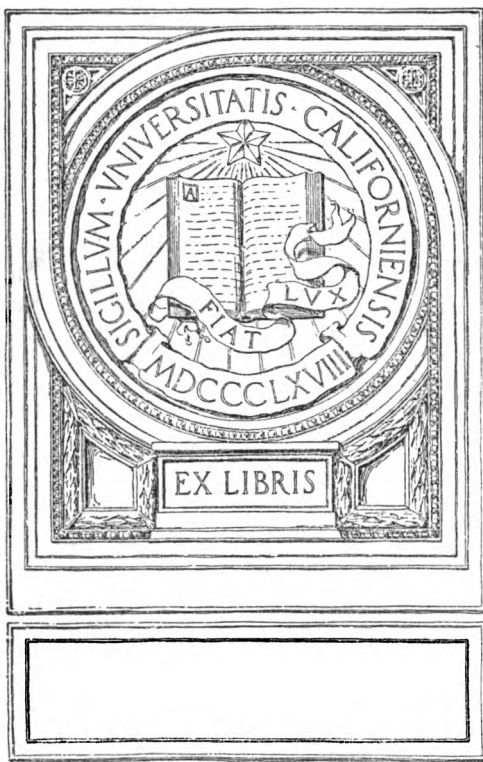




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**TENNESSEE RIVER AND TRIBUTARIES
NORTH CAROLINA, TENNESSEE
ALABAMA, AND KENTUCKY**

• **LETTER**

FROM

THE SECRETARY OF WAR

TRANSMITTING

**WITH A LETTER FROM THE CHIEF OF ENGINEERS
REPORTS ON PRELIMINARY EXAMINATION AND A
PARTIAL SURVEY OF TENNESSEE RIVER AND TRIBU-
TARIES IN NORTH CAROLINA, TENNESSEE
ALABAMA, AND KENTUCKY**



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TABLE OF CONTENTS.

	Page.
Letter of transmittal.....	vii
Letter of the Chief of Engineers, United States Army.....	1
Report of the Board of Engineers for Rivers and Harbors.....	4
Report of the district engineer.....	9
Authority for examination and surveys.....	9
Tennessee River above Chattanooga.....	13
Tennessee River, Chattanooga to Florence.....	19
Chattanooga to Browns Island.....	19
Hales Bar Lock and Dam.....	21
Muscle Shoals section.....	22
Original condition.....	24
Present condition.....	24
Tennessee River, Florence to Paducah.....	30
Original condition.....	34
Existing projects.....	34
Present condition.....	35
Clinch River.....	37
Holston River.....	41
French Broad River.....	44
Little Tennessee River.....	49
Richland River.....	52
Hiwassee River.....	53
Sequatchie River.....	58
Gunters Creek.....	59
Paint Rock Creek.....	59
Elk River.....	60
Bear River.....	61
Beech River.....	62
Duck River.....	63
Big Sandy River.....	65
General discussion.....	65
Objects of proposed survey.....	66
General industrial situation.....	67
Hydroelectric situation.....	70
Improvement for navigation.....	75
Existing information.....	78
Timeliness of survey.....	80
Summary.....	81
Recommendations.....	82
Report of the division engineer.....	82
Appendix A. Report of Assistant Engineer Gerard H. Matthes.....	85
Existing surveys.....	85
Stream flow and rainfall data.....	87
Floods and low water flow.....	105
Preservation of regimen.....	109
Water power.....	111
Earthquakes.....	115
Appendix B. Report of Prof. J. A. Switzer on the water power of the Tennessee River Basin.....	117
General.....	117
The present development of water power.....	118
The undeveloped water power.....	119
Possible power developments.....	120
Tennessee River, Chattanooga to Riverton.....	120
Tennessee River, beginning to Chattanooga.....	120

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III

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Appendix B. Report of Prof. J. A. Switzer—Continued.	Page.
Clinch River and tributaries.....	120
Powell River.....	121
Emory and Obed Rivers.....	121
Holston River and tributaries.....	121
French Broad River and tributaries.....	122
Little River.....	122
Little Tennessee River.....	123
Hiwassee River.....	123
Cumberland Plateau streams.....	124
Elk River.....	124
Duck River.....	124
Calculation of power at these sites.....	124
Power projects which have not materialized.....	127
Appendix C. Report on geology and mineral resources of Tennessee River Basin by Rolf A. Schroeder.....	128
General geology and topography.....	128
Drainage.....	129
Caves, sinks, and subsurface passages.....	129
Mineral deposits.....	130
Abrasives.....	130
Asbestos.....	131
Barite.....	131
Bauxite.....	132
Building stone.....	132
Clay.....	133
Chrome and nickel.....	133
Coal.....	134
Copper, pyrite, sulphuric acid, gold, silver.....	135
Feldspar, quartz, mica, gem stones.....	135
Graphite.....	136
Iron ore.....	136
Lime and cement.....	137
Manganese.....	137
Phosphate rock.....	138
Sand, gravel, and broken stone.....	138
Salt and gypsum.....	138
Talc and soapstone.....	139
Zinc and lead.....	139
Appendix D. Industrial survey of Tennessee River Basin from Knoxville to Riverton, by E. D. Stratton and J. G. Kitchell, of Southern Railway Development Service.....	140
Transportation.....	140
Industrial survey of cities and towns in Tennessee River Basin.....	141
Appendix E. Report of Mr. D. C. Boy on the natural resources of that portion of the Tennessee River Basin traversed by and immediately tributary to the Carolina, Clinchfield & Ohio Railway.....	141
General.....	141
Location.....	141
Watercourses.....	141
Resources.....	141
Power.....	141
Timber.....	142
Minerals.....	142
Transportation facilities.....	145
Industrial development.....	145
Summary.....	146
Appendix F. Letter of Dr. T. Poole Maynard.....	147

LIST OF TABLES.

Table 1. Discharge of Tennessee River at five localities.....	10
Table 2. Heights of five highest floods on record.....	11
Table 3. Appropriations for Tennessee River and tributaries.....	11
Table 4. Commercial statistics of Tennessee River above Chattanooga.....	16
Table 5. Bridges across Tennessee River above Chattanooga.....	17
Table 6. Traffic through Hales Bar Lock.....	26

TABLE OF CONTENTS.

	Page.
Table 7. Statement of traffic through Muscle Shoals Canal.....	26
Table 8. Commercial statistics of Tennessee River between Chattanooga and Florence.....	26
Table 9. Bridges across Tennessee River between Chattanooga and Florence..	27
Table 10. Traffic through Colbert Shoals Canal.....	33
Table 11. Commercial statistics of Tennessee River, Florence to Paducah.....	34
Table 12. Bridges across Tennessee River below Florence.....	34
Table 13. Bridges across Clinch River and tributaries.....	39
Table 14. Commercial statistics of Clinch River.....	40
Table 15. Bridges across Holston River and tributaries.....	43
Table 16. Commercial statistics of French Broad River.....	47
Table 17. Bridges across Little Tennessee River and tributaries.....	51
Table 18. Commercial statistics of Hiwassee River.....	56
Table 19. Clinch River gage records.....	88
Table 20. Holston River gage records.....	89
Table 21. French Broad River gage records.....	90
Table 22. Little Tennessee River gage records.....	92
Table 23. Hiwassee River gage records.....	94
Table 24. Tennessee River (upper section) gage records.....	95
Table 25. Tennessee River (middle section) gage records.....	97
Table 26. Tennessee River (lower section) gage records.....	100
Table 27. Precipitation in or near drainage basin of Clinch River.....	102
Table 28. Precipitation in or near drainage basin of Holston River.....	102
Table 29. Precipitation in or near drainage basin of French Broad River.....	103
Table 30. Precipitation in or near drainage basin of Little Tennessee River...	103
Table 31. Precipitation in or near drainage basin of Hiwassee River.....	103
Table 32. Precipitation in valley of main Tennessee River (upper section)....	103
Table 33. Precipitation in or near drainage basin of Elk River.....	104
Table 34. Precipitation in valley of main Tennessee River (middle section)...	104
Table 35. Precipitation in or near drainage basin of Duck River.....	104
Table 36. Precipitation in valley of main Tennessee River (lower section)....	104
Table 37. Summary of precipitation in drainage basin of Tennessee River.....	105
Table 38. Occurrence of high and low water stages on the Tennessee River at Florence, Ala., 1872-1920.....	106
Table 39. Minimum recorded flow of tributaries of Tennessee River.....	108
Table 40. List of earthquakes in Southern Appalachian Region.....	115

REPORT ON SURVEY.

Report of the district engineer.....	147
Summary.....	162
Recommendations.....	164
Report of the division engineer.....	165
Appendix A. Report of Warren R. King, district engineer, United States Geological Survey, on stream flow measurements.....	167
Appendix B. Report of Assistant Engineer Gerard H. Matthes on flood profiles..	173
Appendix C. Report of Assistant Engineer Gerard H. Matthes on level datums of the Chattanooga district.....	174
Engineer Department datum.....	175
Capt. T. A. Bingham's precise levels of 1895.....	176
Mean sea-level datum.....	177
The 12.83-foot correction.....	178
Present status of Tennessee River levels.....	178
Appendix D. Report by Maj. Harold C. Fiske, Corps of Engineers, on map making by combined use of aerial photographs and ground survey methods.	179
Requirements of Map of Tennessee River Survey.....	180
Appendix E. Report by Maj. Harold C. Fiske, Corps of Engineers, on silt deposits in the Tennessee River.....	189
Appendix F. Extract from War Department Document 1039, by Col. C. Keller, Corps of Engineers, December 13, 1919.....	190
Appendix G. Report of Assistant Engineer Gerard H. Matthes on cost estimates..	193
Construction cost.....	194
Annual power production cost.....	194
Unit cost of power produced.....	195
Costs of hydroelectric and steam-electric power compared.....	195

	Page.
Appendix H. Report of State Geologist Wilbur A. Nelson on examination made of Coulter shoals as location for dam site.....	198
Appendix J. Report of Assistant Engineer Gerard H. Matthes on power available at Coulter shoals.....	198
Water supply.....	198
Head.....	200
Power output.....	200
Load factor.....	203
Backwater curve.....	203

LIST OF TABLES.

Table 1. Expenditures for stream gauging in Tennessee Basin.....	169
Table 2. Status of stream gauging in Tennessee Basin.....	170
Table 3. Check distances used in construction of topographic map of Tennessee River Valley of 1921-22.....	188
Table 4. Fuel cost of steam-generated electric power.....	196
Table 5. Operating and maintenance costs of six steam plants of modern design in Massachusetts.....	197
Table 6. Total annual production cost of steam-electric and hydroelectric utility plants in the superpower zone.....	197
Table 7. Low water flow at Coulter shoals for period 1900-1921.....	200
Table 8. 24-hour power at 80 per cent efficiency available at Coulter Shoals site with permanent crest of dam at elevation 799 above mean sea level....	202

LETTER OF TRANSMITTAL.

WAR DEPARTMENT,
Washington, May 18, 1922.

THE SPEAKER OF THE HOUSE OF REPRESENTATIVES.

MY DEAR MR. SPEAKER: I have the honor to transmit herewith a letter from the Chief of Engineers United States Army, of the 16th instant, together with reports dated January 15, 1921, and March 15, 1922, by Maj. Harold C. Fiske, Corps of Engineers, on preliminary examination and a partial survey, respectively, of Tennessee River and tributaries, North Carolina, Tennessee, Alabama, and Kentucky, authorized by the river and harbor act approved June 5, 1920.

Sincerely yours,

JOHN W. WEEKS,
Secretary of War.

VII

TENNESSEE RIVER AND TRIBUTARIES, NORTH CAROLINA, TENNESSEE, ALABAMA, AND KENTUCKY.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, May 16, 1922.

Subject: Preliminary examination and a partial survey of Tennessee River and tributaries, North Carolina, Tennessee, Alabama, and Kentucky.

To: The Secretary of War.

1. There are submitted herewith, for transmission to Congress, reports dated January 15, 1921, and March 15, 1922, by Maj. Harold C. Fiske, Corps of Engineers, on preliminary examination and a partial survey, respectively, of Tennessee River and tributaries, North Carolina, Tennessee, Alabama, and Kentucky, authorized by the river and harbor act approved June 5, 1920.¹

2. The report on preliminary examination, which is exhaustive and instructive, contains a description of the Tennessee River and each of its 14 principal tributaries, and covers an inquiry which while on the lines of broad public policy is in many respects unusual and leads to the proposal of a very expensive survey on a scale never before attempted in connection with river and harbor improvements. No complete survey of this drainage basin such as now proposed has ever been made, but the main stream and the more important tributaries have either been surveyed or examined to an extent, generally speaking, sufficient to determine the needs of navigation. The investigation clearly shows that there is no present necessity for additional surveys to determine the need of facilities other than those provided for by projects already adopted by Congress for the transportation by water of freight originating or consumed in the tributary region. It seems clear that the purpose of the survey is primarily to gain full knowledge of water-power possibilities, not only on the main stream and its navigable tributaries, but on all tributaries even though not susceptible of navigation; and secondarily to assemble complete information with respect to physical, commercial, and industrial conditions and their relation to navigation and power development. It is estimated that such a survey would cost \$515,800, an amount far more than the entire appropriation usually provided by Congress in any one year for all "Examinations, surveys, and contingencies of rivers and harbors."

3. Following the preliminary examination, a short section of the stream—that below Knoxville—was selected for survey, and the progress report thereon covers, first, the collection of data relating to the use of the flow of the river and its tributaries for the combined

¹ Illustrations not printed.

interests of navigation and of water-power development; and second, a study of the most favorable section of the river to demonstrate the navigation and power possibilities and form a concrete example of what could be accomplished by extending such study to the whole river and developing therefrom a well coordinated plan covering the entire basin. The district engineer believes that the information so far obtained establishes the desirability of finishing the studies now well under way, being confident that when completed they will point to a clear and well-defined line of procedure whereby a large amount of hydroelectric power now wasted annually in the upper section of the Tennessee River can be conserved to the public and that a navigable depth of 6 feet on the section from Knoxville to Chattanooga can be provided by canalization at a cost to the Government well below any that has heretofore been indicated by previous projects. He therefore recommends an appropriation of \$250,000 for continuing the survey during the coming fiscal year.

4. The division engineer is in marked disagreement with the report of the district engineer in so far as it stresses the power possibilities and subordinates navigation improvement thereto. He is of the opinion that the survey should have the interests of navigation primarily in view, that an analysis should be made of the benefits to navigation of any proposed project for the purpose of determining the maximum amount which the United States would be justified in expending for the increased navigation facilities. Such a survey, he estimates, would cost considerably less than the \$250,000 estimated by the district engineer for work during the coming year.

5. These reports have been referred, as required by law, to the Board of Engineers for Rivers and Harbors, and attention is invited to its report herewith. The board, while recognizing the economic value of the comprehensive survey contemplated by the district engineer, finds itself more in accord with the views expressed by the division engineer, and furthermore takes exception to the theoretical basis on which the estimate of the value of the water-power plant proposed at Coulter Shoals is prepared, there being considerable doubt as to whether the favorable results, assumed as a result of a tentative analysis, can be realized. In the opinion of the board the advisability of making the proposed survey in all its ramifications should be left to Congress for a decision as to the policy it desires to establish in the light of the data thus far obtained. Should Congress decide in favor of the survey as proposed or of a modification thereof to include only the factors directly affecting a power-navigation project, a special appropriation should be made.

6. After due consideration of the above-mentioned reports, I concur in the views of the Board of Engineers for Rivers and Harbors, and therefore recommend that these reports be submitted to Congress for a decision on the merits of the question and the policies involved, and as to what further expenditures should be authorized to complete the investigation. It seems to me that the many and varied benefits which will necessarily follow the construction of dams on these waterways providing both power and navigation are so great in amount and so far-reaching in application that it is highly advisable as a matter of enlightened public policy to obtain at as early a date

as possible the information which the proposed survey will develop. In these days of super power the direct effect of the power development possible on these streams will reach to every part of the country east of the Mississippi and the economic result be manifest throughout the entire extent of our country. I therefore recommend that an appropriation of \$250,000 be made for continuing the work and that the full amount for completing the survey, viz, \$515,800, be authorized.

LANSING H. BEACH,
Chief of Engineers.

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS.

SYLLABUS.

The Board of Engineers for Rivers and Harbors deems it advisable to submit to Congress the reports of the preliminary examination and the partial survey in order that the data thus far developed may be known to Congress and that Congress may indicate the scope and extent of any additional surveys desired and appropriate the funds necessary therefor.

[Second indorsement.]

BOARD OF ENGINEERS, FOR RIVERS AND HARBORS,
Washington, D. C., April 4, 1922.

To the CHIEF OF ENGINEERS UNITED STATES ARMY:

1. The Board of Engineers for Rivers and Harbors has carefully reviewed the district engineer's reports on preliminary examination and partial survey of "Tennessee River and tributaries, in North Carolina, Tennessee, Alabama, and Kentucky," authorized by the river and harbor act approved June 5, 1920.

2. The district engineer's survey report covers, as far as available funds would permit, first, the collection of data relating to the use of the flow of the river and its tributaries for the combined interests of navigation and of water power development; and, second, the study of the most favorable section of the river to demonstrate the navigation and power possibilities and form a concrete example of what could be accomplished by extending such study to the whole river and developing therefrom a well coordinated plan covering the entire basin. The data collected cover in considerable detail information on stream flow, flood profiles, vertical control system, maps, and silt deposits in the Tennessee River. As a measure of economy, aerial photography was used as an aid in mapping.

3. After a review of the existing navigation and power situation on the Tennessee, the section below Knoxville was selected for detailed study. Consideration of navigation improvement, power generation, foundation conditions, etc., led to the selection of the first dam site at Coulter Shoals, 40 miles below Knoxville, where a 50-foot head would be available at standard low water. A navigable depth of 6 feet is thus obtained to near the head of the main river 4 miles above Knoxville.

4. At the Coulter Shoals site a water power could be created having a minimum low water 24-hour capacity of 14,000 horsepower. For 90 per cent of the time in an average year 18,400 horsepower would be available, while for 57 per cent of the time 40,000 to 44,000 horsepower may be developed. At extreme flood the minimum capacity is 24,500 horsepower. The initial estimated cost of the entire project at Coulter Shoals is \$6,346,500 and \$257,300 annually for operation if built by the Government. If built by private parties, the first cost would be materially increased by expenses connected with financing and the annual operating costs would be augmented by a charge of at least \$400,000 for interest and by the costs for insurance, taxes, legal expenses, and other additional overhead. No discussion is attempted of these factors of cost to private interests, the assumption being that

parties concerned would make their own estimates. Dependence for marketing the power is based on connection with two power lines of the existing net passing within 10 miles of the Coulter Shoals site. Transmission would be principally to Knoxville, where there is now a demand for power in excess of the supply and prospects of increased demand through the growth of this industrial center. An important factor appears to be the possibilities of the creation of a superpower zone by interconnection with existing and prospective lines, whereby excess power could be sent throughout eastern Tennessee and into northern Georgia and the Carolinas. Under certain assumption as to load factors and sale values of the power the district engineer concludes that the plan has sufficient possibilities to justify further study of details and preparation of detailed designs.

5. The district engineer further discusses the benefits to navigation through the construction of the Coulter Shoals Dam, showing that it replaces three dams considered in the 1909 survey report. The cost to navigation is \$1,080,900 if only the locks and accessories are chargeable thereto at Coulter Shoals, as against a present estimated cost of \$5,000,000 for the three locks and dams proposed in the 1909 survey report, no part of which could be assessed against power as, with the low heads afforded, the power would not be worth developing.

6. A location for the second high power-navigation dam about 30 miles below Coulter Shoals is given consideration, but no data are available to warrant even its tentative adoption. These two dams, with the Caney Creek Dam now included in the approved 3-foot project, and with the open river improvement below, would form a through navigable channel of moderate capacity between Chattanooga and Knoxville and might lead to some revival of river traffic between these points.

7. The suggestion is made as to the construction of additional power-navigation dams extending 6-foot navigation down to Chattanooga, but present information does not warrant the presentation of an outline for such further improvement. The district engineer believes, however, that information so far obtained establishes the desirability of finishing the studies now well under way, being confident that, when completed, they will point to a clear and well-defined line of procedure whereby two or three million dollars' worth of hydroelectric power now wasted annually in the upper section of the Tennessee River can be conserved to the public, and that a navigable depth of 6 feet on this section from Knoxville to Chattanooga can be provided by canalization at a cost to the Government well below any that has heretofore been indicated by previous projects; he therefore recommends an appropriation of \$250,000 for continuing the survey during the coming fiscal year.

8. The division engineer is in marked disagreement with the district engineer's report in so far as it stresses the power possibilities and subordinates navigation improvement thereto. He is of the opinion that the survey should have the interests of navigation primarily in view, that an analysis should be made of the benefits to navigation of any proposed project for the purpose of determining the maximum amount which the United States would be justified in expending for the increased navigation facilities. The division engineer furthermore considers that the survey can be completed

along the line he suggests for a total sum much less than the \$250,000 estimated by the district engineer for work during the coming year.

9. The board, while recognizing the economic value of the comprehensive survey contemplated by the district engineer, finds itself more in accord with the views expressed by the division engineer. Exception is furthermore taken to the more or less theoretical basis on which the estimate of the value of the water-power plant proposed at Coulter Shoals is prepared, there being considerable doubt as to whether the favorable results, assumed as a result of a tentative analysis, can be realized.

10. This report has been prepared by the district engineer in the belief that in providing for the investigation Congress desired full information covering present and potential hydroelectric developments, the mineral and industrial resources within the area covered by the watershed, drainage, flood protection, and such other subjects incidentally arising in connection with the problem of improving the stream for navigation. The report seems to cover these subjects as thoroughly as is possible with the information obtainable within the limit of available funds. In the report on preliminary examination he describes first the Tennessee River and then each of its principal tributaries, of which there are 14. Of the latter, 3 are under improvement and 5 others have been improved to some extent in the past. While some of the tributaries not now under improvement can be navigated for a few miles above their mouths during high stages in the Tennessee, they are for the most part unnavigable. Most of the tributaries have either existing or potential water power.

11. The Tennessee River is 652 miles long and is navigable, though not continuously at low stages, throughout its length. With its tributaries, it forms a system of waterways capable of being navigated or of being made navigable for something like 1,350 miles. The watershed of the river covers an area of about 40,800 square miles. There has been expended on the Tennessee River in improvements and maintenance since 1852 upward of \$14,000,000, resulting in several disconnected navigable reaches with minimum low-water depths of from 3 to 6 feet, the intervening reaches having minimum depths of but 1 to 2 feet. The construction of the Wilson Dam at Muscle Shoals is now a complete though temporary bar to all through navigation. There are varied natural resources of greater or less potential value within the Tennessee watershed, and many of these could be converted into marketable products if power were available in large quantities and at low cost. It is expected by local interests that this condition would be brought about through the development of hydroelectric energy which they think would follow a survey and the clearing up of all questions of doubt regarding the amount of potential power, the quantity and availability of raw materials, and the bearing these have upon the question of navigation. There is now on the Tennessee River at Hales Bar a developed water power of 62,000 horsepower, and on six of the tributaries of 132,700 horsepower. The undeveloped water power is estimated from incomplete data at from 800,000 to over 2,000,000 horsepower, but such development would require the storage of a considerable part of the surplus discharge. This in turn would to some extent favorably affect flood heights in the valley below. Such storage, however, would run into the billions of cubic feet, would flood valuable lowlands, and be enormously expensive. Farm owners in this section are greatly attached

to their homes, and as they have little interest in hydroelectric power, opposition to the flooding of lowlands may be expected from this source.

12. The commerce on the river has fluctuated from year to year and, until very recently, shown a tendency to decrease, even on the lower section, where there is year-around navigation, with depths of 4 to 5 feet or more. It should be stated, however, that the river has not been in condition to encourage through navigation above Florence, and there are no large towns on the lower reach.

13. As above noted, the district engineer states that in the Tennessee River Basin there is a possible 2,000,000 horsepower of undeveloped hydroelectric energy and that much of it is capable of being developed economically. All of it may have some effect upon existing or potential development in the interest of navigation. The problems involved are surrounded by much uncertainty which would be removed by a comprehensive survey. He believes that with a large quantity of cheap electric energy available the many undeveloped resources in the vicinity, in addition to the minerals brought from a distance, will make a large development of industries of various kinds possible and create a commerce that will require additional transportation facilities, but he also believes that private initiative can not be relied on to make the costly and laborious investigations that are called for in order to arrive at a plan of orderly and economical development in which navigation, water power, industry, and other features shall receive due attention and adequate treatment. To determine the various questions involved, the district engineer therefore recommends an extension of the survey to include studies of all present or potential hydroelectric developments, the mineral and industrial resources of the basin, floods, drainage, and such other allied subjects as may have an appreciable influence on any project for river improvement that may finally be recommended and should be coordinated with it.

14. By indorsement on the report on preliminary examination, the division engineer states that in 1909 a complete survey of the Tennessee River was made from its origin to its mouth, for the benefit of navigation, and covered all necessary physical information on which to base a project for improvement. A project was adopted and no new survey for such purpose is now needed. Danger from floods in the Tennessee Valley is of comparatively small importance, and extensive flood control by use of storage reservoirs does not seem to be demanded and therefore a survey for this purpose is not required. There is now one large power development on the main stream at Hales Bar and another under construction at Muscle Shoals. Aside from these the undeveloped water power on the Tennessee is not large and requires no extensive surveys. Many of the tributaries have power possibilities, some of which have been developed. Substantially all the water rights on the more important of the tributaries have already been acquired by water power corporations. The main purpose of the survey is clearly to determine conclusively water power possibilities and their relation to allied subjects. In the opinion of the division engineer the extent, character, and cost of the survey proposed are of such unusual magnitude that it should not be carried out until the further views of Congress can be obtained.

15. This inquiry is in many respects unusual and the report of the district engineer on preliminary examination is exhaustive and instructive, but it leads to the proposal of a very expensive survey on a scale never before attempted in connection with river and harbor improvements. While no complete survey of the drainage basin has been made, the main stream and the more important tributaries have either been surveyed or examined to an extent sufficient, generally speaking, to determine the needs of navigation. Therefore, justification for the survey must be looked for elsewhere than in connection with navigation. The question of flood control must likewise be laid aside as having no great bearing upon the present inquiry. The damage from occasional floods in the Tennessee basin is so small when compared with the hundreds of millions of dollars that would have to be expended for effective relief by the use of storage reservoirs that great weight can not be given to this phase of the subject. It seems clear that the purpose of the survey is primarily to gain full knowledge of water power possibilities, not only on the main stream and its navigable tributaries, but on all tributaries even though not susceptible of navigation, and secondarily, complete information with respect to physical, commercial, and industrial conditions and their relation to navigation and power development. This purpose is commendable but Congress has never sanctioned an inquiry of this kind and therefore no authority appears to exist for making it.

16. Owing to the unusual character of the present report and the great expense involved in making a survey of the kind recommended by the district engineer, it is considered advisable to present an estimate of cost which in a communication dated January 27, 1922, the district engineer places at \$515,800. It is obvious that such a survey can not be made with funds provided in river and harbor acts for "examinations, surveys, and contingencies," as the amount involved is much greater than the entire appropriation for such purposes in any one year. As to the advisability of making the proposed survey in all its ramifications, the board is of the opinion that the data thus far developed should be made known to Congress, leaving to that body the decision as to the policy it desires to establish. Should Congress decide in favor of the survey as proposed or of a modification thereof to include only the factors directly affecting a power-navigation project, a special appropriation should be made. It is recommended, therefore, that the reports be submitted to Congress as the inquiry has now been sufficiently advanced to warrant a decision on the merits of the question and the policies involved, and as to what further expenditures should be authorized to complete the investigation.

17. Since the object of the survey is to coordinate questions of terminal facilities, water power, or other related subjects with any suggested improvement for navigation, the board is obviously forced to state that such coordination on the broad scale suggested by the district engineer would be impracticable unless a comprehensive survey and investigation should disclose some feasible plan of coordination.

For the board:

H. TAYLOR,
Brigadier General, Corps of Engineers,
Senior Member of the Board.

PRELIMINARY EXAMINATION OF TENNESSEE RIVER AND TRIBUTARIES.

UNITED STATES ENGINEER OFFICE,
Chattanooga, Tenn., January 15, 1921.

From: The District Engineer.

To: The Chief of Engineers, United States Army
(Through the Division Engineer).

Subject: Report on preliminary examination of Tennessee River and Tributaries.

1. The river and harbor act of June 5, 1920, contains the following section pertaining to the Tennessee River:

SEC. 2. That for examinations, surveys, and contingencies for rivers and harbors for which there may be no special appropriation the sum of \$400,000 is hereby appropriated: *Provided*, That no preliminary examination, survey, project, or estimate for new works other than those designated in this or some prior act or joint resolution shall be made: *Provided further*, That after the regular or formal reports made as required by law on any examination, survey, project, or work under way or proposed are submitted no supplemental or additional report or estimate shall be made unless ordered by a concurrent resolution of Congress: *And provided further*, That the Government shall not be deemed to have entered upon any project for the improvement of any waterway or harbor mentioned in this act until funds for the commencement of the proposed work shall have been actually appropriated by law.

Every report submitted to Congress in pursuance of this section or of any provision of law for a survey hereafter enacted, in addition to other information which the Congress has heretofore directed shall be given, shall contain a statement of special or local benefit which will accrue to localities affected by such improvement and a statement of general or national benefits, with recommendations as to what local cooperation should be required, if any, on account of such special or local benefit.

The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys to be made at the following-named localities, and a sufficient sum to pay the cost thereof may be allotted from the amount provided in this section:

* * * * *
Tennessee River and tributaries, in North Carolina, Tennessee, Alabama, and Kentucky.

The Chief of Engineers has given verbal instructions to the effect that in connection with the proposed survey it is the intention of Congress to include studies of present or potential hydroelectric developments, the mineral and industrial resources of this region, drainage, flood protection, and such other allied subjects as may reasonably appear to have an appreciable influence on the project that may be finally recommended for adoption for the improvement of navigation.

In compliance with the foregoing item of law and with instructions given verbally and those contained in the letter of the Chief of Engineers of June 30, 1920,¹ the following report is submitted:

2. The Tennessee River is formed by the confluence of the French Broad and Holston Rivers at a point about 4½ miles upstream from Knoxville, and flows in a southwesterly direction through eastern Tennessee and northern Alabama to the city of Guntersville, Ala.; then, turning to a northwesterly course, it crosses western Tennessee and Kentucky and joins the Ohio River at Paducah, Ky. It is a stream of unusually stable regimen and traverses a country of remarkable mineral, forest, and agricultural resources, and of constantly increasing industrial activities. Its upper tributaries have their sources in the Appalachian Mountains of western North Caro-

¹ Not printed.

lina, southwestern Virginia, northern Georgia, and eastern Tennessee. The Tennessee River itself is 652 miles long. Together with its tributaries it forms a system of internal waterways capable of being navigated by steamboats more than 1,350 miles and by rafts and flatboats for an additional distance of more than 1,050 miles, thus making a system of navigable waters 2,400 miles in extent. The whole system, on account of the stable banks and beds of the streams, the unfailing supply of water coming from the mountains of the streams' sources, and from the fact that they are seldom obstructed with ice, is exceptionally susceptible of improvement. The Tennessee River as to its length is distributed by States as follows: 388 miles in Tennessee, 192 miles in Alabama, 48 miles in Kentucky, 13 miles between Tennessee and Kentucky, and 10½ miles between Alabama and Mississippi. The watershed of the river covers an area of about 40,800 square miles, of which 22,000 square miles lie in Tennessee, 7,000 in Alabama, 5,000 in North Carolina, 3,400 in Virginia, 1,800 in Georgia, 1,050 in Kentucky, and 550 in Mississippi. (H. Doc. No. 50, 57th Cong., 1st sess.)

3. The discharge of the river at five well-distributed and important localities on the river is shown in the following table:

TABLE 1.

	Miles from head of river.	Extreme low water.		Extreme high water.	
		Gauge.	Cubic feet per second.	Gauge.	Cubic feet per second.
Knoxville.....	4.5	-1.5	1,750	45.1	270,000
Chattanooga.....	188.0	.0	4,800	58.6	393,000
Florence.....	395.6	-.8	7,230	32.5	444,000
Riverton.....	426.0	-.6	7,500	53.5	504,000
Paducah.....	652.0	1 - .57	10,601	54.3	(*)

* Lowest gauge reading of record, -0.7.

† H. Doc. No. 50, 57th Cong., 1st sess.

‡ Maximum discharge at Paducah has never been calculated.

4. The occurrence of maximum floods is confined to the months of February, March, and April, but occasionally floods of sufficient height to cause damage to growing crops have occurred in the summer and fall months. Such floods have recently occurred in the summer of 1898, 1916, and 1920. The larger cities and towns on the Tennessee River are situated on high ground well above high water, except Chattanooga, Decatur, and Paducah. Of these, Decatur is least affected and Paducah suffers more from floods in the Ohio than from those in Tennessee River. Three of the recorded high waters have covered the main streets in the business section and large areas in the residence districts of Chattanooga. The city of Chattanooga, in fear of a repetition of maximum floods, has within the past year had prepared plans and estimates for protective works estimated to cost about \$10,000,000. There are no protective works in existence on the Tennessee River or any contemplated as far as known, except as noted for Chattanooga. Heights above low water of the five highest floods of record are shown in the following table:¹

¹ The point of least fluctuation is in the vicinity of Lock 6, Muscle Shoals Canal, where the difference between high water and low water planes is about 8 feet.

TABLE 2.

Location.	Year of occurrence.				
	1847 ¹	1867	1875	1886	1897
Knoxville.....	33.1	45.1	43.2	29.6	26.0
Chattanooga.....	53.0	² 58.6	54.0	52.2	37.9
Bridgeport.....	27.7	39.24	37.17	.....	27.2
Decatur.....	22.5	28.5	27.6	27.0	24.7
Florence.....	25.1	31.1	29.4	28.0	32.5
Riverton.....	40.8	47.8	.....	.....	50.3
Johnsonville.....	41.0	44.8	45.3	42.1	48.0
Paducah.....	.....	52.0	44.3	³ 50.4	50.9

¹ Taken from "Flood notes on tributaries," by Commissioner Henry L. Abbott, Annual Report, 1875, p. 635.

² Water Supply Paper, No. 353 (1913), p. 95.

³ Maximum, 54.3 from Ohio River.

5. The principal tributaries of the Tennessee River, of which previous examinations by the Engineer Department have been made, are Clinch River, Holston River, French Broad River, Little Tennessee River, Richland River, Hiwassee River, Sequatchie River, Gunter's Creek, Paint Rock River, Elk River, Bear River, Beech River, Duck River, Big Sandy River. Only two of the foregoing afford year-round navigation for steamboats, the French Broad for 26 miles and the Hiwassee for 19 miles above their respective mouths. A number of the others are navigable for steamboats for considerable distances at high stages, while for the rest steamboat navigation is confined to the length of back water from the parent stream. Most of the tributaries listed and many others of smaller flow contain important potential water powers.

6. A consolidated statement of appropriations for the Tennessee River and its tributaries is given in Table 3.

TABLE 3.—*Appropriations for Tennessee River and tributaries.*

Section of river.	Previous projects, expenditures.	Present project.	Total.
(1) Knoxville to Kellys Ferry.....	\$51,406.94	.....	\$51,406.94
(2) Above Chattanooga:			
(a) Caney Creek Lock and Dam.....	.....	\$25,614.57	25,614.57
(b) Open-channel work.....	809,679.02	1,605,466.78	2,415,145.80
Total.....	809,679.02	1,631,081.35	2,440,760.37
(3) Chattanooga to Riverton:			
(a) Open-work channel (entire section).....	1,000,160.41	.....	1,000,160.41
(b) Hales Bar Lock and Dam (construction).....	.....	1,306,388.87	306,388.87
(c) Hales Bar to Browns Island.....	.....	628,331.13	628,331.13
(d) Florence to Colbert Shoals.....	.....	1,019,068.17	1,019,068.17
(e) Colbert Shoals Canal.....	.....	2,313,000.00	2,313,000.00
(f) Muscle Shoals Canal.....	3,191,726.50	.....	3,191,726.50
Total.....	4,191,886.91	4,266,788.17	8,458,675.08
(4) Below Riverton.....	545,245.35	962,129.71	1,507,375.06

¹ Includes clearing the pool of snags and other work since the lock was opened for use.

TABLE 3.—*Appropriations for Tennessee River and tributaries—Continued.*

Section of river.	Previous projects, expenditures.	Present project.	Total.
(5) Expenditures for operating and care of canals and locks:			
(a) Hales Bar Lock and Dam.....			\$59,671.47
(b) Muscle Shoals.....			² 1,551,758.00
(c) Colbert Shoals Canal.....			³ 151,274.57
Total for operation and care.....			1,762,704.04
Total for main trunk of Tennessee River.....			14,220,921.49
(6) Tributaries:			
(a) French Broad River.....			240,000.00
(b) Holston River.....			11,837.24
(c) Little Tennessee River.....			8,150.84
(d) Clinch River.....			61,822.43
(e) Hiwassee River.....			123,065.71
(f) Elk River.....			7,600.00
(g) Duck River.....			13,000.00
Total for tributaries.....			465,476.22
Total for Tennessee River and tributaries.....			14,686,397.71

² Does not include expenditures for fiscal year 1920.³ Including expenditures for fiscal year ended June 30, 1920.

7. Many minerals abound in the region adjacent to the Tennessee River (see Charts I, II, III, and IV),¹ of which the most important is coal. Of this mineral the division engineer, central division, stated in his review of the report of Maj. H. Burgess, district engineer, on reexamination of Tennessee River (H. Doc. No. 981, 64th Cong., 1st sess., p. 44):

The coal resources of the region adjacent to the Tennessee are enormous. It is conservatively estimated that in the Waldens Ridge field there are about 200,000 acres of land that are coal bearing, with some 800,000,000 tons of coal upon them. That part of the Cumberland Mountain field which is tributary to the Tennessee River, and not more than 30 miles from it, covers about 300,000 acres and has a very high grade of coke and by-product coal, one seam averaging 42 inches in thickness without parting or refuse of any kind. It is estimated by State officials connected with the State mines that there is in the counties of Roane, Anderson, Campbell, and Scott, on the upper Tennessee River, an area of about 665 square miles containing coal that will yield from 2,500 to 5,000 tons per acre, the coal in these counties being not less than 22 feet in thickness in from three to nine workable seams.

The next in importance and in extent of distribution are the iron ores, which are of three kinds—red Clinton ores, brown ores, and magnetite. The red ores occur flanking the foot of the Appalachian Mountains on the west (see Chart I) in a belt which extends from New York to Alabama. In the Tennessee basin it is developed at Rockwood, Lafollette, and Chamberlain. The brown ores occur in irregular masses and pockets in residual clays and sometimes as beds. These deposits are found in widely scattered localities, principally in central east Tennessee, western middle Tennessee, and near Russellville, Ala., and Cartersville, Ga. The United States Geological Survey estimates 500,000,000 tons of reserve iron ores in Tennessee. Magnetite occurs near the Tennessee-North Carolina line near Cranberry, N. C. The Cranberry mine produced 60,326 gross tons of magnetite iron ore in 1918. Another important mineral resource of this district is phosphate rock. (See Chart III.) Of a total of 1,941,700 tons of phosphate rock produced in the United

¹ Illustrations not printed.

States in 1919, Tennessee produced 867,283 tons. Production of some of the chief mineral substances and their products in the Tennessee River Basin for the year 1919 is shown in the following table:

	Tons.
Barite.....	33, 111
Marble.....	36, 350
Coal.....	14, 670, 000
Coke.....	1, 080, 000
Copper.....	15, 727, 867
Sulphuric acid.....	368, 898
Iron ore.....	538, 000
Lime.....	200, 000
Cement.....	346, 500
Phosphate.....	867, 283
Zinc.....	50, 363

Other mineral substances in the basin which have been developed in paying quantities are lead, manganese, chromite, corundum, feldspar, gypsum, mica, pyrite, quartz, salt, talc, tripoli, clay, granite, gravel, limestone, sandstone and slate. (See Charts III and IV.)

8. For the purpose of presenting other features required by regulations to be presented in a preliminary report, the main trunk of the Tennessee River will be considered under three heads: (1) Above Chattanooga. (2) From Chattanooga to Florence. (3) From Florence to Paducah. In addition, each important tributary will be separately treated.

TENNESSEE RIVER ABOVE CHATTANOOGA.

9. This section of the river, 188 miles long, consists of a series of deep pools where the slopes are less than the average, the velocities moderate, and navigation easy at all stages; and, separating these pools, shoals consisting usually of sand, gravel, and boulder bars, in most cases held up by rock reefs crossing the thread of the stream. Occasionally the bars are caused by widening of the stream where sand and gravel are deposited due to the diminishing current at high stages. Over the bars, the velocities are greater than the average and depths too slight for easy use of boats. The total fall in the 188 miles is 174.7 feet, being an average of about 0.96 foot per mile. For short distances the slope is as great as 15 feet to the mile.

10. The earliest plan for the improvement of this section of the Tennessee River was presented to the commissioners of the State of Tennessee by Col. S. H. Long, Corps of Topographical Engineers, in 1831, being a report of his examination made the year before, from Kingsport on Holston River in Sullivan County, Tenn., to the Tennessee-Alabama State line, 48 miles below Chattanooga. (H. Ex. Doc. No. 167, 43d Cong., 2d sess.) Following this plan, the State of Tennessee began work in 1832 under an allotment of \$60,000, made by the State in 1830, for the improvement of the rivers of east Tennessee. In 1842 the State appropriated \$100,000 for the improvement of its rivers and the upper Tennessee again received an allotment. Colonel Long's project provided for securing a minimum depth of 2 feet in the channel at low water and work

¹ Pounds.

was, accordingly, confined to the obstructions having a less depth, the estimated cost being \$10,500. It is not known how much the State spent and the results were of doubtful value, judging from a statement in a report made in 1853 by Col. J. C. McClellan, Corps of Topographical Engineers, as follows:

I made an examination of the river as far down as Chattanooga (formerly Ross Ferry), 188½ miles below Knoxville, to ascertain the effect at a moderate stage of the water, of the improvements made some years ago by the State of Tennessee, and how far these improvements conformed to those recommended by Colonel Long, Topographical Engineers, in his report to the commissioners of the State. I found that in every case except one, at the "Suck," the plans of improvement recommended by Colonel Long had been disregarded and, in every instance, the dams constructed have either failed to give the water the requisite depth at low water or have changed the direction of the channel and given the current a velocity so great that steamboats require the aid of warps to stem it, and it is at imminent risk that flatboats, in which all produce of the country above Knoxville passes down the river, passes these dams at all, and frequent and serious losses have been sustained by them in passing a dam, being forced by the current and wrecked upon the dam below.

11. The first appropriation made by the Federal Government for the improvement of the river above Chattanooga was included in the act of August 30, 1850, and its amount was \$50,000. In 1852 Col. J. C. McClellan, Corps of Topographical Engineers, was directed to make an examination and prepare plans for the improvement of the Tennessee River from Knoxville to Kelly's Ferry, 22 miles below Chattanooga. His report was dated September 1, 1853. This project also provided for a 2-foot depth of channel, to be obtained as in the preceding plan by a combination of excavation and contraction. The estimated cost of the proposed work between Knoxville and Kelly's Ferry was \$125,425.02. Later reports refer to the work as having been well done. Parts of the dams are visible to this day although for the most part they have been covered by later work. The project was modified in 1871, extending the depth of channel to be obtained to 3 feet at average low water but following the same general methods for obtaining this result. This project was based on an examination and report made under the direction of Maj. Walter McFarland, Corps of Engineers. (See Report of the Chief of Engineers for 1871, pp. 502-507, for 1872, pp. 488-494 and H. Ex. Doc. No. 76, 42d Cong., 2d sess.) The estimated cost was \$175,000, exclusive of \$51,406.94 previously spent. The estimate was increased to \$255,000 in 1877; \$300,000 in 1884; \$340,000 in 1890. A revised project was adopted by the river and harbor act of August 18, 1894, extending the depth to be obtained to 3 feet at extreme low water and increasing the estimated cost to \$650,000. The estimated cost was again increased in 1907 to \$1,709,000.

12. The present project adopted by the act of July 25, 1912, and based on report of the survey of 1909 (H. Doc. No. 360, 62d Cong., 2d sess.), provides for continuing the improvement for 3-foot depth of channel by former methods of regulation over the entire stretch of 188 miles, except that 24.6 miles were to be covered by a pool formed by a lock and dam at the foot of Caney Creek Shoals, suitable for 6-foot navigation over Caney Creek, Long Island, Farmer, Seven Island, Wilson, Bacon, and Bogart Shoals. The amount spent on all previous projects was \$809,849.02, not including an amount of \$51,406.94 spent prior to 1871. The original estimated cost of constructing Caney Creek Lock and Dam was \$1,298,687 (H. Doc. No.

360, pp. 51-53); subsequent to the date of that report a survey was made to determine the extent of flowage damages, the total being \$315,670.60, making the total estimated cost of the lock and dam \$1,614,357.60, which was reduced by the Chief of Engineers (H. Doc. No. 360, p. 2) to the round figure of \$1,600,000. The open channel work was estimated at \$1,057,081.35, making the original total of the project estimate \$2,657,081.35. (H. Doc. No. 981, 64th Cong., 1st sess., p. 8.) Estimates for both classes of work were later increased until the present estimated cost of the lock and dam is \$2,225,614.57, and of open channel work, \$2,650,000, a total of \$4,875,614.57, exclusive of \$809,679.02 spent on previous projects. Practically all of such work as has been accomplished in this section has been done by hired labor. In 1872 a contractor absconded with many debts unpaid and thereafter no other contracts for improvements in this stretch were let. The risks attendant upon work of this character, the difficulty of estimating quantities, and the necessity of making changes make contract work expensive and subject to controversy. The present condition of this section of the Tennessee River, as given in the Annual Report of the Chief of Engineers for 1920, is as follows:

Condition at end of fiscal year.—Surveys and borings had been made and a suitable site found for the Caney Creek Lock and Dam, but the necessary lands had not been purchased and no construction work had been done. The open-channel work was about 57 per cent completed. Thirty shoals remained to be improved in addition to those partially improved at the end of the year. These shoals, according to the last estimate, require 84,400 cubic yards of rock excavation, 685,500 cubic yards of gravel excavation, and dikes containing 26,100 cubic yards of excavated stone and 84,600 cubic yards of quarried stone; but present indications are that the actual quantity of rock excavation will greatly exceed the estimate.

Although some of the most obstructive shoals have been improved and light-draft traffic has been made possible over the entire section, except at periods of extreme low water, it will not be practicable to have through traffic between Knoxville and Chattanooga throughout the year until the entire project is completed. The minimum available depth in the section of the river above Chattanooga was about 1 foot at extreme low water. The river is navigable for 1-foot draft throughout the year, and usually navigable for 2-foot draft from December 15 to August 1, and for 3-foot draft from January 1 to June 1. Draft of 4 feet and over is occasionally practicable for short disconnected periods during the high-water months of January to April, inclusive. When the Knoxville and Loudon gauges read 0.5, 2-foot navigation was practicable; and for each additional foot of reading on these gauges 1 additional foot of navigable water depth is practicable.

13. A map of this section of the river is contained in the Annual Report of the Chief of Engineers for 1876, page 710. The published reports of examinations and surveys of the Tennessee River above Chattanooga are as follows:

(a) Examination from Kingsport on Holston River to Tennessee-Alabama State line, embracing the section under consideration. (H. Ex. Doc. No. 167, 43d Cong., 2d sess.)

(b) Examination from Knoxville to Kellys Ferry, 22 miles below Chattanooga, made in 1853. (Reprinted in H. Doc. No. 461, 56th Cong., 1st sess., pp. 34 and 35.)

(c) Examination between Chattanooga and Knoxville. (Annual Report, 1871, pp. 502-507; 1872, pp. 488-494; H. Ex. Doc. No. 76, 42d Cong., 2d sess.)

(d) Instrumental survey from Knoxville to Chattanooga made in 1891 under authority of the act of September 19, 1890. (H. Ex. Doc. No. 252, 52d Cong., 2d sess.; annual report, 1893, pp. 2335-2375.)

(e) Instrumental survey between Knoxville and Chattanooga made in 1909 by authority of the act of March 3, 1909. (H. Doc. No. 360, 62d Cong., 2d sess.)

14. Published documents containing special reports on this section are:

(a) Report of the Board of Engineers for Rivers and Harbors on Locks and Dams in Tennessee River above Chattanooga and between Chattanooga and Browns Island, August 13, 1915. (H. Doc. No. 1, 64th Cong., 1st sess.)

(b) Report on reexamination of Tennessee River, Tenn., Ala., and Ky. (H. Doc. No. 981, 64th Cong., 1st sess.)

TABLE 4.—Commercial statistics of Tennessee River above Chattanooga, Tenn.

Year.	Amount.	Value.	Year.	Amount.	Value.	Year.	Amount.	Value.
	<i>Tons.</i>			<i>Tons.</i>			<i>Tons.</i>	
1892.....	91,187	(1)	1902.....	478,268	\$4,296,822	1912.....	474,953	\$4,424,446
1893.....	71,026	(1)	1903.....	552,268	4,483,229	1913.....	469,685	2,707,363
1894.....	100,818	(1)	1904.....	562,677	4,473,617	1914.....	305,616	2,356,992
1895.....	265,256	\$4,527,589	1905.....	486,406	6,673,532	1915.....	402,622	3,403,995
1896.....	623,915	2,788,022	1906.....	475,515	3,443,923	1916.....	345,604	2,212,509
1897.....	256,331	2,693,802	1907.....	596,380	3,830,790	1917.....	613,243	3,535,925
1898.....	218,378	2,425,068	1908.....	621,500	3,187,620	1918.....	529,299	2,801,202
1899.....	269,552	2,839,037	1909.....	370,400	2,320,360	1919.....	589,660	4,961,624
1900.....	380,607	2,847,629	1910.....	341,540	2,570,880			
1901.....	294,607	2,604,931	1911.....	394,176	2,856,227			

¹ Values not given in annual reports.

TABLE 5.—Bridges across Tennessee River above Chattanooga.

Location.		Owner.	Character— fixed, swing, vertical lift, etc.	Num- ber of spans.	Channel spans.					Remarks.	
Miles above mouth.	Nearest town, street, etc.				Clear width normal to channel.			Clear height above.			
					Left.	Center.	Right.	Mean low water.	Mean high water.		
464.1	Market Street, Chat- tanooga, Tenn.	Hamilton County, Tenn.	2-leaf bas- cule. ¹	7	.....	258.3	.....	66.6	13.4	Clearance above crest of Hales Bar Dam and extreme high water of 1867.
464.2	Walnut Street, Chat- tanooga, Tenn.do.....	Fixed.....	6	301	301	301	$\left\{ \begin{array}{l} 2 \text{ 94.5} \\ 3 \text{ 89.5} \\ 4 \text{ 84.5} \end{array} \right.$	$\left\{ \begin{array}{l} 2 \text{ 41.3} \\ 3 \text{ 36.3} \\ 4 \text{ 31.3} \end{array} \right.$		Do.
470.7	Hixson, Tenn.	(Cincinnati, New Orleans & Texas Pacific Ry.	Vertical lift.	15	300	$\left\{ \begin{array}{l} 103.9 \\ 60.9 \end{array} \right.$	$\left\{ \begin{array}{l} 50 \\ 7 \end{array} \right.$		Clearances are above extreme low water and high water of 1875. Lift span raised and lowered.
591.3	Loudon, Tenn.	Southern Railway Co.	Fixed.....	11	200	.....	.....	76.5	28.4	Clearances are above extreme low and high water.
644.8	Knoxville, Tenn.	Cherokee Land Co.	.....do.....	16	.....	235	.....	79	32.5	Do.
646.5	.....do.....	Louisville & Nashville R. Co.	.....do.....	3	.....	254	.....	75.5	29	Do.
647.3	.....do.....	Southern Railway Co.	.....do.....	8	.....	126	.....	66.5	20	Do.
647.6	Day Street, Knoxville, Tenn.	Knox County, Tenn.	.....do.....	7	.....	238	.....	84.5	35	Clear heights measured at center of arch above extreme high and low water.

¹ Each leaf rises from the pier at an angle of 45 degrees when open.

² Left.

³ Center.

⁴ Right.

15. A list of the bridges in this section is given in Table 5. Inasmuch as Market Street, Chattanooga, is taken as the line of division between the upper and middle sections of the river, the Market Street bridge is included in the list above Chattanooga.

16. The principal existing terminal facilities on the Tennessee River above Chattanooga are as follows: At Knoxville there is a wharf and a warehouse with endless chain conveyor; these are privately owned but open to public use. Other privately owned and used facilities consist of one log incline, six derricks, and one locomotive crane at Knoxville; one railroad incline for transferring cars to and from barges, each at Round Island and head of Caney Creek Shoals; one derrick each at Concord and Lenoir City; one locomotive crane at Chattanooga. Public use of some of these facilities is frequently possible on payment of reasonable charges. There are many unimproved private landings, at some of which are sheds or small warehouses without regular attendants, where owners receive and care for freight at reasonable charges. As a rule, these landings have no improvements or facilities and freight is subject to theft and to damage by mud and water. There is no interchange of through traffic between river and rail.

17. No water power plants have been developed in this section of the river, but three power transmission lines parallel the river and furnish electric power to all points of importance in the valley. (See Chart V.) In the report upon which the existing project is based, Document No. 360, Sixty-second Congress, second session, two dams of sufficient height (20 feet) for power development were located, one at Little River Shoals, 17.3 miles below the head of the river (see No. 29 on Chart VI), and one at Caney Creek Shoals, 90.4 miles below the head of the river (see No. 30 on Chart VI). The latter was adopted as a part of the project and the former was left to become a part of a possible revision of the project to provide complete canalization of the river when sufficient commerce developed to justify the expense. The possible development of power at these two dams was discussed in the report, Document No. 360, pages 28-30. Later investigations with a core drill led to the selection of a site for the Caney Creek Lock and Dam about 2 miles below that originally proposed. The proposed height of the dam in the new location is about 26 feet. The fall of 174.7 feet between Knoxville and Chattanooga has suggested the possibility of still other combined power and navigation dams in this section, but no studies that have been made warrant an expression of opinion as to the feasibility of any further developments along this line.

18. The valley of the Tennessee River in this section is bordered on the west by the escarpment of Waldens Ridge, which contains beds of red iron ore and coal. Red iron ore is mined along the part of this escarpment (see Chart I), especially in Roane County, which was the biggest producing county in Tennessee in 1919, being credited with a production of over 71,000 long tons of pig iron with a value of more than \$2,000,000. Coal is mined in horizontal strata forming the upper portion of Waldens Ridge. It is carried down the western tributary valleys of the Tennessee River on spur lines owned and operated by the coal companies to the railroad extending along the east foot of the escarpment for its entire length. In three instances these spur lines have been continued to the Tennessee River some 5 miles beyond

the railroad and two of these extensions are still in use. All these spurs from the coal mines could be extended to the Tennessee River if transportation conditions made such a course advisable. Marble is quarried extensively in this valley between Knoxville and Kingston. Several marble belts cross the Tennessee River near Loudon and Knoxville. The quarrying and preparing of this marble for commercial use is an important industry in the vicinity of Knoxville, and with suitable river transportation it would seem that much of this product could be shipped by water and further growth of this industry would be encouraged. Bauxite, barite, and manganese are mined in this region; lime is manufactured in connection with the marble industry, and the digging of river sands is of some importance at various localities.

19. The question of land reclamation does not enter into the problem of improving the river above Chattanooga. All of the cities and towns on the upper river lie well above flood plain except Chattanooga at the lower end of the section and the matter of flood protection for that city is discussed in connection with the middle section of the river.

20. There are no channels of approach for this section except as its tributaries and the lower sections of the Tennessee River may be considered as such, and these are described under their respective sections of this report.

TENNESSEE RIVER—CHATTANOOGA TO FLORENCE.

21. This section of the river is more varied in its characteristics than either of the other two. Ten miles below Chattanooga the river enters the "mountain section" and for the next 12 miles it had, in its original condition, the characteristics of a mountain torrent of unusual size. It was confined between steep rocky banks, its low water width in places being only 250 feet. The mountains continue close to the river on each bank until Hales Bar, 33 miles below Chattanooga, is reached, although for the lower 11 miles of that distance the slope was more gentle. Below Hales Bar the river again changes its character, growing broader and having a more moderate slope. The river valley widens and from Bridgeport to Decatur on the right bank and from Decatur to Florence on the left bank comparatively level country lies between the river and the mountains or high hills. This level land attains a width of 20 miles or more in places. From the head of Browns Island to Florence is the Muscle Shoals section, where the river, unable to wear away its hard flinty bed, has eroded its banks in places to a width of a mile and a half. The mean width of the river in this section is 950 feet above Bridgeport; 1,340 feet between Bridgeport and Guntersville; 1,210 feet between Guntersville and Decatur, and 1,900 feet between Decatur and Browns Island. In the Muscle Shoals section the width varies from a minimum of 1,000 feet to more than a mile and a half.

22. *Chattanooga to Browns Island.*—The date when the improvement of this section was first undertaken and by whom is indefinite. The earliest examination and report of record in available official reports is embraced in the report of an examination made by Col. S. H. Long, Corps of Topographical Engineers, in 1830. However, his report refers to previous work at the "Boiling Pot" in the following language: "The improvements contemplated at this place,

in addition to those already made, which are to be regarded as valuable in so far as they have contributed to enlarge the passage through which the river has to pass, etc." The project formulated by Colonel Long provided for a channel 2 feet deep at low water and of requisite width. Seven obstructions were listed as requiring improvement: Ross Towhead, Tumbling Shoals, Suck Point, the Suck, the Boiling Pot, the Skillet, and the Pan. All except the first named seem to have afforded sufficient depth and required only straightening to make safer downstream navigation, and certain changes to enable boats bound upstream to warp through swift places. Under date of September 1, 1853, Col. J. C. McClellan, Corps of Topographical Engineers, submitted a report of an examination made by him from Knoxville to Kellys Ferry, the latter point being the lower limit of the stretch to be improved under the authority of the act of August 30, 1852, appropriating \$50,000. This first appropriation by the Federal Government was expended under the direction of Colonel McClellan, following the general plan and attempting to secure the same dimensions of channel as provided in Colonel Long's project. In 1868 Mr. W. B. Gaw, assistant engineer, after his examination of the river from Chattanooga to its mouth, submitted to Maj. G. Weitzel, Corps of Engineers, a plan for the improvement of the river between Kellys Ferry and Decatur by the open-channel method designed to give at least 3 feet depth in channel. His estimate of the cost was \$58,901. Major Weitzel, in transmitting this report, stated that he did not consider it adequate and recommended an increase of about 50 per cent. In 1870 bids were received for carrying out Mr. Gaw's plans at Widows Bar, Bellefonte Bar, Gunters Reef, Gunters Bar, and Limestone Bar. The lowest bid for this work which was not undertaken was \$18,725. In 1872 Maj. Walter McFarland, Corps of Engineers, submitted an estimate of \$73,000 for securing a 3-foot channel between Browns Ferry and the mouth of Short Creek, about 2½ miles above Guntersville. In 1874, Assistant Engineer W. G. Williamson, under direction of Major McFarland, made an examination of this entire section of the river. This report and estimate are not to be found among the records of this office. In 1891 and 1894, Capt. George W. Goethals, Corps of Engineers, submitted plans and estimates for the improvement of the following shoals:

Shoal:	Estimated cost.
Bridgeport Island.....	\$34, 100. 00
Widows Bar.....	600. 00
Gunters Reef.....	4, 000. 00
Beards Reef.....	8, 905. 00
Coles Bend Bar.....	10, 854. 25
Paint Rock (Allens) Bar.....	9, 121. 20
Flint River.....	2, 942. 50

Within the next few years following 1891 dredging was done at all of the foregoing localities except Coles Bend Bar, as well as at Ross Towhead, Tumbling Shoals, Williams Island, and the Skillet. In 1900 a small party was sent over the river from Bridgeport to Decatur to cut trees, pull snags, and to excavate high points of reefs, in an attempt to give temporary relief at a few of the worst obstructions. Slight improvement in channel depth was reported.

23. For the open-channel improvement of this section there was no well-defined or comprehensive plan of improvement, succeeding reports submitted generally proposing to carry the improvements a little farther by dredging a little deeper and in some cases to attempt to enlarge the high-water section by removing bowlders and cutting trees, until Maj. Dan C. Kingman, Corps of Engineers, submitted a report, dated March 25, 1901, and published as Document No. 50, Fifty-seventh Congress, first session. Major Kingman's plan provided for the improvement of the river between Scott Point and Lock A by open-river method, for 5-foot depth of channel, at an estimated cost of \$770,640. The lock and dam below Chattanooga, which at the time of Major Kingman's report was to be located at Scott Point, was later shifted 15 miles farther downstream to Hales Bar. Deducting the estimated cost of removing the obstructions lying between the two sites of the lock and dam, the estimate for improving the river from Hales Bar to Lock A was \$739,885. The original project dated back to 1868, and with minor changes it held until Major Kingman's project was adopted by act of March 2, 1907. This project was modified by the act of July 25, 1912, to provide for the construction of a lock and dam at Crow Creek to give 6-foot navigable depth to the lower entrance to Hales Bar Lock; again, by act of July 27, 1916, providing the substitution of concrete locks with low dams at Widows Bar and Bellefonte for the high dam under the first modification. The two locks with low dams, together with open-channel work to obtain a channel 150 feet wide and 5 feet deep at extreme low water through all shoals in the 138 miles in the section between the head of Browns Island and Hales Bar, except those in the reach to be canalized, constitute the existing project.

24. *Hales Bar Lock and Dam.*—Under date of February 20, 1900, Maj. Dan C. Kingman, Corps of Engineers, submitted a report recommending the construction of a lock and dam at Scott Point, 18 miles below Chattanooga, to overcome the rapids of the mountain section, the dam to be of such height as to back the water up to Chattanooga and secure at the lowest stages a navigable channel not less than 5 feet in depth for the entire distance; the lock with walls and gates to be of such height that it could be used until the river attained a stage of 35 feet on the Chattanooga gauge, and to be 60 feet wide and 300 feet long between quoins. The estimated cost, including land for the lock site, was \$888,624. Under the act of April 26, 1904, the city of Chattanooga was granted the privilege of building the lock and dam at Scott Point. Having failed within the four months stipulated to avail itself of the opportunity, the privilege of undertaking the work was vested in the Chattanooga & Tennessee River Power Co. Investigation of foundation conditions led to the selection of a site at Hales Bar, 15 miles below Scott Point, and the act was amended to accept this site January 7, 1905. Contract was made with the power company September 12, 1905; actual work was begun October 18, 1905; final closure was made October 27, 1913; and the first lockage was made November 1, 1913. Under the contract the United States prepared the plans, supervised the construction, and provided gates, valves, operating machinery, and other appurtenances of the lock. The estimated cost to the United States, made in 1908, was \$214,720; the actual cost was \$236,388.87. The cost to the power company, exclusive of power-house superstructure

and installations, was about \$6,686,700. The lock and dam give a pool 6 feet deep at low water up to Chattanooga, 33 miles.

25. *Muscle Shoals section.*—The value of the improvement of this section of the Tennessee River for a commercial highway at an early date attracted the attention of statesmen. In 1824 John C. Calhoun, Secretary of War, asserted that a canal around Muscle Shoals was of great national importance. Accordingly, in 1828, the Board of Internal Improvement was directed by act of Congress, approved May 23, 1828, to make an examination of the Muscle Shoals with a view to their improvement for navigation. The project of the board, which included the construction of certain works at Colbert Shoals, was approved in March, 1831. For the purpose of carrying out the plan proposed by the board, Congress appropriated 400,000 acres of the public lands lying within the State of Alabama, which were to be sold and the proceeds applied to the construction of the works recommended by the board. The plan provided for a canal along the north or right bank. Communication between the southern shore of the river and the canal was to be accomplished by three pools, one below Browns Ferry, one below Elk River Shoals, and one below Big Muscle Shoals, the pools thus created to be connected by three separate canals with locks. The work was intrusted to the State of Alabama with the single condition that the work should begin at deep water near Florence and extend upstream as far as the funds available would permit. However, the money received from the sale of the lands was manifestly inadequate for the complete works proposed by the board and the commissioners of the State of Alabama applied for and received congressional authority to apply the funds available to the construction of that section of the canal which was to connect Lambs Ferry and Campbells (Bainbridge) Ferry. A board of engineers directed to report on the proposed modification stated in report dated March 25, 1831, that it was "a plan not presented or approved by this board * * * that it will overcome about 14 miles and six-eighths of the impediments of the river; but after passing these a boat can not go farther for want of the improvement to pass over the impediments above and below." This same criticism is made of the two sections of canal existing to-day. However, the work was begun in 1831 and water was let into the canal in July, 1836. The prediction of the board quoted above seems to have been fulfilled, judging from a letter from Mr. Thomas Williams, the chief engineer of the canal, dated May 14, 1838, which stated: "There were a few days ago about 70 large flatboats loaded with cotton (all of which had passed through the canal) lying at Campbells Ferry waiting for a rise in the river to carry them over the Little Muscle Shoals. Many more are detained by the shoals above the canal. The steamer *Holston*, of more than 100 tons burden, and intended for the upper Tennessee trade, passed up the canal some time ago but I am told is detained by shoals above the canal." The difficulties combined with failure of attempts to secure further appropriations, either from Congress or from the Legislature of Alabama, caused its abandonment and the canal fell into disuse.

26. Under authority of the act of March 3, 1871, Major McFarland, Corps of Engineers, made a resurvey of the Muscle Shoals section. (Report of the Chief of Engineers for 1872, pp. 495-501.) Major

McFarland recommended the complete reconstruction of the old State canal and the construction of a canal to surmount Elk River Shoals and another at Little Muscle Shoals. The estimated cost was \$3,676,000. Later the location of the Elk River Shoals Canal was changed to the left bank of the river and open-channel work was resorted to at Nances Reef and Little Muscle Shoals, so that the only portion of Major McFarland's plan as it exists to-day in the completed project is the rebuilt State canal from Lambs Ferry to Bainbridge Ferry. Actual work was started in 1875 and the improvements were completed in 1890 at a cost of \$3,191,726.50. In 1889 a board of engineers was directed to make an examination and report on the improvement of Little Muscle Shoals. The board recommended a canal from near Lock 9 to the city of Florence at an estimated cost of \$1,537,762, and stated that to extend the canal to deep water below the Florence bridge would cost an additional sum of \$1,500,000. This plan did not receive congressional approval.

27. By Special Orders, No. 8, office Chief of Engineers, March 9, 1907, a board of Engineer officers was directed to examine "the present conditions of the improvements * * * with a view to permitting the improvement of this section of the river by private or corporate agency in conjunction with the development of water power, etc." Following this other boards were convened to make further studies and reports looking to combined navigation improvement and water-power development. These reports are fully described in House Document No. 1262, Sixty-fourth Congress, first session, which is a report of a survey of Tennessee River between Browns Island and the railroad bridge below Florence, Ala., and is the basis of the work now in progress at Dam No. 2. The existing project, adopted by letter of the President dated February 23, 1918, under authority of section 124 of the national defense act of June 3, 1916, provides for the construction by the United States of locks, dam, and power house 2.7 miles above the railroad bridge at Florence, Ala. The pool above the dam will submerge Muscle Shoals Canal Locks 3 to 9, inclusive, and provide a minimum depth of 9½ feet from the dam up to old Lock 2, and leave in operation Locks 1 and 2 of the Big Muscle Shoals section of the old canal and Locks A and B of the Elk River Shoals section.

28. In its original condition the Muscle Shoals afforded a minimum depth of 3 inches at low water, from 6 to 8 inches being found in a number of places. (Chief of Engineers' Report for 1872, p. 497.) No upstream navigation was attempted except in rare instances where a steamboat built below the shoals was brought up over the shoals for use on the upper river. This was a difficult and hazardous undertaking and could only be accomplished during the high stages. The present depth available in the two divisions of the canal is 5 feet, but this depth was not obtained between the two divisions nor in the portions of the Muscle Shoals subdivisions above and below the canal, a minimum extreme low-water depth of 1 foot being found at Lock A. (Chief of Engineers' Report for 1917, p. 1221.) The expenditure for operation and maintenance of Muscle Shoals Canal from its completion in 1890 to and including the fiscal year ended June 30, 1919, aggregates \$1,551,758. The commerce that has passed through the canal is given in Table 7.

29. *Original condition.*—(a) Chattanooga to Hales Bar: This section known as the "mountain section," was a serious obstruction to navigation at low-water periods on account of small depth, steep slopes, and consequent excessive currents. The minimum low-water depth was about 0.7 foot. Light-draft navigation was possible for the greater part of the year.

(b) Hales Bar to Browns Island: This section had a gentle slope, but was obstructed by numerous gravel and rock bars, with a minimum available low-water depth of about 0.8 foot. Light-draft navigation was possible for the greater part of the year.

(c) Browns Island to Florence: This section consisted of rock shoals with steep slopes, swift currents, and low-water depth as small as 3 inches, separated by pools of greater depths and slight slopes. The shoals were a barrier to upstream navigation at all times, and to downstream traffic except at high stages and at great hazard.

30. *Present condition.*—(a) Hales Bar: The lock and dam were completed and placed in operation November 1, 1913, and provide 6-foot navigation up to Chattanooga, 33 miles.

(b) Hales Bar to Browns Island: The construction at Widows Bar Lock and Dam has been under way since June, 1920. Open-channel work done under previous projects had improved low-water conditions so as to make light-draft traffic practicable, except at low water. The river is usually navigable for 15-inch draft throughout the year, for 2-foot draft from December 15 to September 1, for 3-foot draft from January 1 to July 1, for 4-foot draft from January 1 to May 15. Drafts of 5 and 6 feet are occasionally practicable for disconnected periods, during the high-water months of January to April, inclusive. When the Bridgeport and Decatur gauges read 1 and 0.5, respectively, 2-foot navigation is practicable, and for each additional foot of reading on these gauges 1 additional foot of navigable depth is practicable.

(c) The construction of the Wilson Dam (Dam No. 2) has temporarily closed the river at that point to navigation at all stages. When completed the pool formed by this dam will supplant the canal from Locks 3 to 9, inclusive.

31. Reports of examinations and surveys and reports of boards of engineer officers for the section between Chattanooga and Florence have been published, as follows:

(a) Survey of Muscle Shoals. (H. Doc. No. 284, 20th Cong., 1st sess., May 14, 1828.)

(b) Examination made in 1830 from Kingsport on the Holston River to the Alabama State line. (H. Ex. Doc. No. 167, 43d Cong., 2d sess.)

(c) Examination in 1853, made by Col. J. C. McClellan, Corps of Topographical Engineers, from Knoxville to Kellys Ferry. (Extract reprinted in H. Ex. Doc. No. 461, 56th Cong., 1st sess., pp. 34 and 35. On p. 36 of Doc. 461 is reprinted the report of a board on Colonel McClellan's plans and work.)

(d) Examination and survey from Chattanooga to the mouth. (H. Doc. No. 271, 40th Cong., 2d sess.; Annual Report, 1868, p. 560.)

(e) Resurvey of Muscle Shoals section, Browns Ferry to Florence. (Annual Report, 1872, p. 495.)

(f) Examination between Guntersville and Browns Ferry and resurvey of Elk River Shoals. (Annual Report, 1877, p. 589.)

(g) Resurvey of Elk River Shoals. (Annual Report, 1888, p. 1598.)
(h) Report of board of engineers on improvement of Little Muscle Shoals. (Annual Report, 1891, p. 2314.)

(i) Complete survey from Chattanooga to Shellmound and detached surveys of Bridgeport Island, Widows Bar, and Gunters Reef. (Annual Report, 1892, p. 1951.)

(j) Detached surveys of Beards Reef, Coles Bend, Paint Rock and Flint River bars. (Reprinted in H. Doc. No. 50, 57th Cong., 1st sess.)

(k) Precise level survey, that part from Decatur to Florence lying in this section. (Annual Report, 1896, p. 1949.)

(l) Topographical survey of Moccasin Bend, to determine advisability of constructing canal across it. (Annual Report, 1900, p. 3005; H. Doc. No. 168, 56th Cong., 1st sess.)

(m) Survey between Chattanooga and Scott Point (the "mountain section"). (H. Doc. No. 461, 56th Cong., 1st sess.; Annual Report, 1900, p. 2956.)

(n) Survey between Bridgeport and Decatur (preliminary report). (H. Doc. No. 577, 56th Cong., 1st sess.; Annual Report, 1900, p. 3008.)

(o) Survey between Scott Point and Lock A. (H. Doc. No. 50, 57th Cong., 1st sess., Annual Report, 1902, p. 1743.)

(p) In response to a resolution of the Senate of January 24, 1905, certain information regarding the improvement of the Tennessee River at the Muscle Shoals Canal. (S. Doc. No. 173, 58th Cong., 3d sess., map of Muscle Shoals section.)

(q) Resurvey of Muscle Shoals section. (Annual Report, 1908, p. 572. Report of the Board of Engineers for which this survey was made is printed as H. Doc. No. 781, 60th Cong., 1st sess.)

(r) Report of Board of Engineers reviewing its previous report on the Muscle Shoals section. (H. Doc. No. 14, 60th Cong., 2d sess.)

(s) Survey of entire Tennessee River. (H. Doc. No. 360, 62d Cong., 2d sess.)

(t) Report of Board of Engineers constituted by Special Orders No. 23, Office Chief of Engineers, October 31, 1911, to consider and report on combined improvement of the Tennessee River at Muscle Shoals for navigation and power development. (H. Doc. No. 20, 63d Cong., 2d sess.)

(u) Topographic survey of creek and river bottom lands from Hales Bar to foot of Browns Island and extending up to high-water plane. (Annual Report, 1914, p. 2565.)

(v) Complete survey of Muscle Shoals section with preliminary designs and estimated cost of structures for combined navigation improvement and water power development. (H. Doc. No. 1262, 64th Cong., 1st sess.)

(w) Report of the Board of Engineers for Rivers and Harbors on locks and dams in Tennessee River above Chattanooga and between Chattanooga and Browns Island. (H. Doc. No. 1, 64th Cong., 1st sess.)

(x) Report on reexamination of Tennessee River, Tenn., Ala., and Ky. (H. Doc. No. 981, 64th Cong., 1st sess.)

(y) Report of the Board of Engineers for Rivers and Harbors on Tennessee River between Chattanooga, Tenn., and Browns Island, Ala. (H. Doc. No. 8, 65th Cong., 3d sess.)

32. Commercial statistics for this section are shown in the following tables.

TABLE 6.—*Traffic through Hales Bar Lock.*

Year.	Amount.	Value.	Year.	Amount.	Value.
	<i>Tons.</i>			<i>Tons.</i>	
1913.....	1,751	\$141,202	1917.....	15,681	\$1,043,903
1914.....	10,394	767,406	1918.....	19,369	1,252,553
1915.....	32,271	352,150	1919.....	18,952	1,186,421
1916.....	20,712	1,220,734			

TABLE 7.—*Statement of traffic through Muscle Shoals Canal.*

Year.	Amount.	Value.	Year.	Amount.	Value.
	<i>Tons.</i>			<i>Tons.</i>	
1891.....	3,131	(¹)	1906.....	26,878	\$1,074,945
1892.....	5,782	(¹)	1907.....	21,100	1,059,770
1893.....	16,636	(¹)	1908.....	12,537	1,097,140
1894.....	24,348	(¹)	1909.....	17,353	1,168,715
1895.....	5,540	\$158,680	1910.....	8,782	626,430
1896.....	3,880	145,721	1911.....	8,962	815,890
1897.....	5,119	88,566	1912.....	5,520	449,857
1898.....	10,264	284,082	1913.....	5,887	579,753
1899.....	14,319	295,003	1914.....	8,585	754,898
1900.....	14,881	297,894	1915.....	7,982	686,096
1901.....	11,925	592,634	1916.....	10,439	836,502
1902.....	7,712	577,505	1917.....	8,677	1,001,288
1903.....	10,571	712,150	1918.....	9,115	1,101,275
1904.....	10,560	559,002			
1905.....	17,796	759,100		314,281	15,722,899

¹ Values not given in annual report.

TABLE 8.—*Commercial statistics of Tennessee River between Chattanooga and Florence.*

Year.	Amount.	Value.	Year.	Amount.	Value.
	<i>Tons.</i>			<i>Tons.</i>	
1892.....	78,820	(¹)	1907.....	267,929	10,567,000
1893.....	77,325	(¹)	1908.....	202,450	8,115,735
1894.....	173,355	(¹)	1909.....	288,750	10,020,990
1895.....	117,357	\$2,099,521	1910.....	207,100	9,367,650
1896.....	131,406	2,686,148	1911.....	292,020	11,151,571
1897.....	247,732	4,078,227	1912.....	316,218	12,187,595
1898.....	224,456	3,598,120	1913.....	192,881	13,865,924
1899.....	253,340	6,118,618	1914.....	207,232	12,334,623
1900.....	229,160	5,499,779	1915.....	171,328	9,311,081
1901.....	129,160	4,584,322	1916.....	208,443	8,963,076
1902.....	137,861	5,567,464	1917.....	170,968	15,611,914
1903.....	297,851	7,439,914	1918.....	141,436	14,341,795
1904.....	173,406	7,204,682	1919.....	164,250	14,486,683
1905.....	175,800	8,475,632			
1906.....	413,751	10,146,386	Total.....	5,791,835	218,804,450

¹ Values not given in annual report.

TABLE 9.—Bridges across Tennessee River between Chattanooga, Tenn., and Florence, Ala.

Location.		Owner.	Character— fixed, swing, vertical lift, etc.	Num- ber of spans.	Channel spans.					Remarks.
Miles above mouth.	Nearest town, street, etc.				Clear width normal to channel.		Clear height above.			
					Left.	Right.	Mean low water.	Mean high water.		
256.5	Florence, Ala.	Louisville & Nashville R. R. Co.	Swing.	18	135	130	34.3	1.0	Clearances are above extreme high and low water. Do. Base of rail at extreme high water; clearance to extreme low water. Piers and abutments completed. Work discon- tinued.	
304.4	Decatur, Ala.	Southern Ry. Co.	do.	11	.....	167	32.8	2.5	
414.4	Bridgeport, Ala.	Nashville, Chattanooga & St. Louis R. R. Co.	do.	4	148	148	37.4	—4		
434.4	Near Oates Island.	Memphis-Chattanooga Ry.	do.	5	190	190	.....	.....

33. Water surface fluctuation at a number of points from Chattanooga to Florence is shown in Table 2, paragraph 4.

34. Only four bridges span the river within the limits of this section, one of which was abandoned before the superstructure was put on the piers. The bridge at Florence is included in this section which is usually considered to terminate below that bridge. The Florence bridge is a combined railroad and highway bridge and is the only one in this section that provides for vehicle traffic. Data pertaining to these bridges are given in Table 9.

35. The principal existing terminals on the Tennessee River between Chattanooga and Florence are as follows: There is a publicly owned wharf and warehouse at Chattanooga with endless-chain conveyor. There are four railway inclines at Chattanooga, two at Decatur, and one at Bridgeport. At Gunter'sville and Hobbs Island the Nashville, Chattanooga & St. Louis Railway owns and operates inclines for transferring cars to and from barges, the cars being ferried between these two points a distance of 21 miles. There is an unimproved landing at Decatur owned by the municipality. Other privately owned and used facilities consist of three locomotives cranes, two log inclines, and two inclined tramways at Chattanooga, one inclined tramway each at Kelly's and Bobo's landings, and two at Decatur; two derricks at Bridgeport and one at Chattanooga. Other landings and facilities are of the same general character as those described above Chattanooga.

36. The one existing water power in this section of the Tennessee River is at Hales Bar, 33 miles below Chattanooga. (See No. 6, Chart V.) It began generating power upon completion of the Hales Bar Lock and Dam in 1913 and has been in successful operation ever since. The plant was built by the Chattanooga & Tennessee River Power Co. under a 99-year lease from the United States. The installed capacity is 62,000 horsepower. The plant is leased to the Tennessee Power Co. and is tied in with that company's two hydroelectric plants on Ocoee River and one on the Caney Fork, a tributary of the Cumberland River, and with steam auxiliaries at Chattanooga, Parksville, and Nashville, generating 44,000 horsepower. Under an operating agreement a 9,000 horsepower steam plant at Knoxville may be called upon at any time for power. The Tennessee Power Co. maintains about 1,000 miles of transmission lines, connecting Knoxville, Maryville, Mascot, Nashville, Chattanooga, and numerous smaller towns.

37. Under authority of section 124 of the national defense act of June 3, 1916, the construction of No. 2 Dam and power plant at Muscle Shoals (see No. 7, Chart V), was started in 1917 and is still in process of building. This plant is located at the site and has the general layout described in Document 1262, Sixty-fourth Congress, first session. The proposed head on this dam is about 95 feet and the installed capacity will be about one-half million horsepower. The plan referred to provides for another hydroelectric plant at proposed Dam No. 3 (see No. 44, Chart VI), but this has not been adopted as a part of the project. Dam No. 3 is designed to have a head of 40 feet, and the two being run-of-river plants, the power at Dam No. 3 as compared with that at No. 2 will be in the ratio of their respective heads.

38. The project for the section between Hales Bar and Browns Island at first included a high dam at Bellefonte (see No. 46, Chart VI), and the possible development of power in connection therewith was then considered. Under date of June 20, 1913, private parties proposed to pay the United States \$330,000 for a 100-year lease of the electric water-power rights of that dam on the basis that it would figure not less than 11,000 horsepower and that the United States build the dam and substructure of the power house. Later other private interests proposed to secure option on the land to be overflowed for the purpose of paying such damages in return for the use of the power. This proposition was later abandoned. Since then, as far as known to this office, no other interest has been manifested in the power feature of that project. In the meantime the project has been changed to provide for two low dams and locks in lieu of the one high lock and dam.

39. The only other probable site for a power dam in this stretch of the river is somewhere in the region of the upper limit of the pool to be created by the construction of Dam No. 3 at Muscle Shoals—between Gunter'sville and Hobbs Island (See No. 45, Chart VI.) Studies have been made for a dam 33 feet high at Coles Bend, 115 miles below Chattanooga, but it was dropped for the time being before being submitted to the department, pending the outcome of the development at Muscle Shoals.

40. The Tennessee River from Chattanooga to about 30 miles below Decatur drains a region underlain by coal measures. (See Chart I.) A number of mines have been operated between Chattanooga and Hales Bar and only one of these is now in operation. It is understood that considerable coal in paying quantities lies within reach of the river in this section, but is not now being mined because of difficulties with land titles, etc. Red iron ore of the Rockwood formation is found along this section of the river, and large deposits of brown iron ore are being mined at Russellville, Ala., about 20 miles south of the river at Florence. Brown iron ore is also found north of Florence along Shoals Creek. A large cement plant is located at Richard City, about 3 miles from the Tennessee River at Bridgeport, and it is proposed to locate another similar plant near the river in the vicinity of Chattanooga. Limestone for building and other purposes is quarried in this section.

41. There is a question of land reclamation by drainage in the vicinity of Huntsville. The only towns materially affected by floods are Chattanooga and Decatur. At high stages, backwater from the Tennessee River rises in several creeks in and around Chattanooga and inundates large areas of residential and manufacturing property. Little, if any, damage is caused by currents. A levee system to cost about \$10,000,000 has been designed for the relief of this situation but not yet adopted. It would have no appreciable effect on the navigable condition of the river. There is some hope that an extensive construction of reservoirs in connection with hydroelectric development above Chattanooga might diminish perceptibly the crests of high flood stages. Only a small undeveloped part of Decatur is reached by floods. Aside from these two cities, the chief interest in flood prevention attaches to the protection of growing crops from untimely floods during summer and fall months. No flood protection

works are under consideration in this section, except as noted for Chattanooga.

TENNESSEE RIVER—FLORENCE TO PADUCAH.

42. This section of the river lies below most of the large tributaries. Duck River being the only one of importance. Navigation at low water is not possible on any of these tributaries, but boats are said to have ascended Duck River at high stages as far as Centerville. The watershed in this section varies in width from about 120 miles at Florence to from 15 to 20 miles for the last 65 miles of its length. The average width of the river is about 1,700 feet between Florence and Colbert Shoals, 2,200 feet on Colbert Shoals, and below that point 1,000 feet. The average fall from Florence to Colbert Shoals is 0.62 foot; through Colbert Shoals section, 2.87 feet; and below Riverton, 0.35 foot per mile. The extreme fluctuation is shown in Table 2, paragraph 4. The section below Riverton, 226 miles, having a moderate and uniform slope and a width nowhere excessive, and being practically free from ice, has always afforded good facilities for navigation. In this reach hard rock occurs in the river bed above elevation of channel bottom at only one place—Big Bend Shoals—about 23 miles below Riverton. The drainage area above Florence is about 30,800 square miles.

43. The improvement of that part of this section lying between Florence and Waterloo, foot of Bee Tree Shoals, was first provided for in 1831, when Congress appropriated 400,000 acres of public land for the purpose of providing the State of Alabama with funds to improve Muscle Shoals, and included in the project certain works at Colbert Shoals. However, the proceeds from the sale of the lands was insufficient for all of the work contemplated and the Colbert Shoals part of the project seems to have been eliminated. In 1868 a contract was let for certain works at Colbert Shoals. Due to the lack of satisfactory progress on the part of the contractor, his contract was annulled in 1872 and the work was completed by hired labor. The report of the survey and examination of 1867, upon which was based the work at Colbert Shoals referred to, dismissed the section below Colbert Shoals with the statement: "As there is ample water below Colbert Shoals, with the exception of Bee Tree, where only a few large isolated rocks make it unsafe at low water, this general view need not be extended." In 1864-65 a reconnaissance of the Tennessee River from Paducah up to Florence was made by a party of the United States Coast Survey. While the map of this survey was remarkably correct and accurate, considering the method of preparing it, it was, nevertheless, not sufficiently in detail to be used as a basis for plans for permanent improvement. It was for the use of the Mississippi Squadron in the operation of its boats. In 1872 (Report of the Chief of Engineers, 1872, page 513), Major McFarland listed the shoals below Riverton which would require "improvements of some kind or other, removing rock or gravel or constructing wing dams, in order to straighten or widen the channel or to give them sufficient depth." This list agrees in the main with those of later dates. Nevertheless, no work of improvement seems to have been undertaken until 1878 and 1879, when a small amount of channel work was done at Duck River Shoals. In 1881, 1882, and 1890 some snagging was done. Up to 1891 a total of about

\$12,000 had been expended on the river below Colbert Shoals. The open river work at Colbert Shoals having proved unsatisfactory in results, due to steep slopes causing swift currents and insufficient depth in channel, in 1888 Col. J. W. Barlow, Corps of Engineers, offered the first plan for slackwater improvement of the Colbert Shoals section, proposing a fixed dam with a lock at the foot of Colbert Shoals and another at the foot of Bee Tree Shoals, having lifts of 14½ and 12 feet, respectively. In 1889 Colonel Barlow, after a further survey, proposed longitudinal dams and two lateral canals with locks. The board of engineers convened to pass on this plan recommended instead one lateral canal in the south bank of the river, about 7.8 miles long, 7 feet deep, 150 feet wide at water surface, and having a combined lock of 25 feet maximum lift at the lower end, and a guard lock at the upper end. The canal was to be separated from the river by an embankment having its crest 1 foot above the highest flood of record. This plan was approved November 28, 1890. In 1891 two locks having lifts of 12 and 13 feet, respectively, and separated by a pool 1 mile long, were substituted for the combined lock. In 1892 the project was again modified by the substitution of one lock of 26 feet lift for the two locks in the previous modification. In 1897 a flood occurred which was 2½ feet higher than any previously recorded. Major Kingman then considered it necessary to raise the embankment 3 feet above this flood, but the estimated cost of construction on that basis proved to be so large that he proposed a plan for two locks and cross dams in the river. This project was considered by a board of engineers in 1899 which reported in favor of continuing the then existing 1892 project. On account of the large increase in the estimate of cost, due to the modification made necessary by the flood of 1897, Major Knight, in 1901, proposed to limit the embankments to such height as would insure the canal being available for use until the river attained a stage at which open river navigation over the shoals became safe and easy. In September, 1902, Major Knight proposed to eliminate the guard lock and to place five weirs in the river embankment. A board of engineers rejected this proposal. In December, 1902, Major Knight recommended transferring the canal to the river bed from Shades Branch to the head of the shoals and transferring the guard lock to Shades Branch. The canal above the guard lock was to be separated from the river by a concrete wall. This plan was approved by the Secretary of War February 17, 1903, and was modified in 1904 by substituting a rock-fill dam with concrete toe wall for a portion of the concrete wall. In October, 1904, Major Newcomer recommended certain changes in the project, and a board of engineer officers constituted by Special Orders, No. 11, War Department, office of the Chief of Engineers, March 20, 1905, was directed to consider and report upon proposed modifications of the project for improving Tennessee River at Colbert and Bee Tree Shoals. The board of engineers recommended changes in the project as follows: (1) To eliminate the guard lock; (2) to raise the walls and gates of the lift lock 4.5 feet to elevation 42 (8.5 feet above low water at the head of the canal); (3) to raise the weir crests 7 feet to elevation 41; (4) to shift the canal trunk toward the land side of the canal right of way; and (5) to raise the river embankment to at least elevation 43,

wasting the surplus excavated material on the river side of the canal where the land had already been purchased for the purpose (authority Secretary of War, June 25, 1904). These changes were approved by the Secretary of War June 12, 1905.

44. The net result of the various changes indicated above leaves the following as the project under which the canal was completed and put into operation: A lateral canal about 8 miles long from near the head of Colbert Shoals to the foot of Bee Tree Shoals, to be 7 feet deep at low water with a lift lock 80 by 350 feet at the lower end of the canal, having a maximum lift of 26 feet, with tops of lock walls and gates at elevation 42 (8.5 feet above low water at the head of the canal) and depth on lower miter sill 6.5 feet. The upper 13,400 feet of the canal lies in the river bed and is separated from the river for about 6,100 feet by a rock-fill dam with concrete toe wall; and for the next 7,300 feet by a concrete wall, the greater length of this wall having its crest at elevation 41 and the rest at 42. For the remaining distance of its length the canal is separated from the river by an earth embankment the least crest elevation of which is at elevation 43, except at five paved waste weirs which have their crests at elevation 41 and which are located opposite the principal waterways discharging into the canal. The upper 13,400 feet of the canal has a bottom width of 180 feet and width at low-water surface of 200 feet. In the earth embankment section of the canal the bottom width is 112 feet and slopes of embankments 1 on 2.

45. With the improvement of Colbert Shoals provided for, necessity for the improvement of the river below presented itself and the first serious consideration was given to the improvement below Riverton by the act of August 17, 1894, which, in appropriating \$100,000 for the improvement of the Tennessee below Riverton, provided that of this sum "\$90,000, or so much thereof as may be necessary, shall be used in the removal of snags and other obstructions to navigation between Riverton and the mouth of the Tennessee, and the remainder of said sum of \$100,000, or so much thereof as may be necessary, shall be used in making a survey of said Tennessee River below Riverton and submitting plans for its improvement." Under this authority a chartered steamboat and derrick boat did some snagging in the late fall and early winter of 1894. The next year efforts favorable to chartering a snag boat and steamboat having failed the construction of such an outfit was undertaken by the officer in charge. In 1897 Major Kingman prepared a plan, based on the maps of the survey of 1894-1896, for improving this section by dredging, involving the removal of more than 650,000 cubic yards of material and more than 60 obstructions. Major Kingman stated that "before this method of improvement is finally adopted as the approved project it is desirable that it should be sufficiently tested to determine what its cost will be and how permanent the improvement thus resulting will prove." To carry out the test a dredging plant was chartered and work was done at seven shoals. The test having demonstrated the success of the method, a plant belonging to the United States took up the work the next year. This plant has been enlarged and improved from time to time and is in operation to-day. The first project was considered to have been adopted by the river and harbor act of July 25, 1868, modified by

acts of September 19, 1890, August 18, 1894, and March 3, 1899. The existing project was adopted by the act of July 25, 1912, and provides for open-channel work by rock excavation and dredging and by contraction works to obtain a channel 150 feet wide and 6 feet deep at ordinary low water, or 5 feet at extreme low water. (Chief of Engineers Report for 1915, p. 1905, and for 1919, p. 1343.) Included in the project was the protection of Livingston Point at the mouth of the river for the purpose of protecting the harbor at Paducah. Livingston Point is a narrow strip of land between the Tennessee and Ohio Rivers. The currents of the two streams are parallel for about a mile on either side of this strip. The Ohio River was rapidly encroaching on this narrow barrier, threatening to provide a new mouth for the Tennessee River which would flow through that opening instead of along the front of Paducah. Four separate allotments aggregating \$80,000 were made for this work and of that amount \$77,367.65 were spent when the work was reported completed in 1901. (Report of Chief of Engineers for 1901, p. 2430.)

46. A map of the Colbert Shoals section is published in report of 1891, page 2320, and in report of 1898, page 1900. Maps of the entire section are published in report of 1913, pages 2498 and 2500. Reports of examinations and surveys and reports of boards pertaining to the section between Florence and Paducah¹ have been published as follows:

(a) Survey of Colbert Shoals, annual report, 1887, page 1747.

(b) Report of Board of Engineers on Improvement of Colbert and Bee Tree Shoals, Tennessee River, annual report, 1891, page 2317.

(c) Precise level survey, part embraced between Florence and a point 4 miles below Pittsburg Landing, annual report, 1896, page 1949.

(d) Report of survey of the mouth of the Tennessee River, Document No. 19, Fifty-fifth Congress, first session (2 maps).

(e) Report of a survey of the river bank at Paducah, Ky., Document No. 644, Fifty-sixth Congress, first session (1 map).

(f) Report of board of engineers on entrance to lift lock at Colbert Shoals Canal, annual report, 1897, page 2292.

(g) Report of board of engineers on proposed modification of the project for improving Tennessee River at Colbert and Bee Tree Shoals, annual report, 1905, page 1751.

47. Commercial statistics for this section are given in Tables 10 and 11.

48. Data pertaining to bridges in this section is given in Table 12.

TABLE 10.—*Traffic through Colbert Shoals Canal.*

Year.	Amount.	Value.	Year.	Amount.	Value.
	<i>Tons.</i>			<i>Tons.</i>	
1911.....	14,245	\$112,603	1917.....	38,286	\$917,173
1912.....	4,112	200,800	1918.....	19,980	336,990
1913.....	30,710	214,888	1919.....	26,412	1,233,947
1914.....	23,734	441,400			
1915.....	32,271	352,150	Total.....	234,164	5,282,358
1916.....	44,414	1,472,407			

¹ Reports pertaining to both this section and the section between Chattanooga not relisted above.

TABLE 11.—Commercial statistics of Tennessee River, Florence to Paducah.

Year.	Amount.	Value.	Year.	Amount.	Value.
	<i>Tons.</i>			<i>Tons.</i>	
1892.....	236, 209	(1)	1907.....	643, 077	\$10, 921, 250
1893.....	344, 553	(1)	1908.....	552, 560	10, 636, 445
1894.....	308, 914	(1)	1909.....	375, 570	9, 020, 840
1895.....	960, 959	\$15, 966, 853	1910.....	464, 030	8, 480, 400
1896.....	864, 061	15, 192, 056	1911.....	431, 113	7, 394, 412
1897.....	390, 167	5, 572, 409	1912.....	373, 625	6, 261, 650
1898.....	602, 916	8, 388, 954	1913.....	480, 105	6, 130, 874
1899.....	462, 307	5, 592, 720	1914.....	449, 956	6, 428, 874
1900.....	1, 237, 009	6, 105, 127	1915.....	471, 006	5, 624, 908
1901.....	658, 102	6, 322, 450	1916.....	403, 578	8, 064, 091
1902.....	1, 056, 270	15, 370, 604	1917.....	416, 304	9, 745, 016
1903.....	848, 758	8, 720, 215	1918.....	280, 602	5, 783, 318
1904.....	871, 380	18, 325, 005	1919.....	245, 759	6, 909, 136
1905.....	663, 606	11, 091, 978			
1906.....	766, 118	10, 930, 000	Total.....	15, 858, 614	228, 979, 585

¹ Values not given in annual reports.

TABLE 12.—Bridges across Tennessee River below Florence, Ala.

Location.		Owner.	Character (fixed, swing, vertical lift, etc.).	Number of spans	Channel spans.				
Miles above mouth.	Nearest town, street, etc.				Clear width normal to channel.			Clear height above—	
					Left.	Center.	Right.	Mean low water.	Mean high water.
22.3	Gilbertsville, Ky.....	Illinois Central R. R. Co.	Swing...	7	185	.....	186	1 56	1 7
78.2	Danville, Tenn.....	Louisville & Nash- ville R. R. Co.	...do....	8	145	.....	145	2 54	2 5.5
96.5	Johnsonville, Tenn...	Nashville, Chatta- nooga & St. Louis R. R. Co.	...do....	8	.....	155	.....	2 50.6	2 1.7

¹ Clearances are to approximate high and low water.

² Clearances are above extreme high and low water.

49. *Original condition.*—From Florence to Colbert Shoals the river was seriously obstructed by rock and gravel bars with a minimum available low-water depth of about 1 foot. The slope was comparatively slight, being 0.62 foot per mile and this entire reach was navigable except during very low stages. The Colbert Shoals section had steep slopes, swift currents, and small low-water depths, the minimum being about 1 foot. The total fall in the 8.7 miles was 24.95 feet, and while low-water navigation was impossible, the entire section was navigable at all stages above medium low water. Below Riverton, 226 miles, the river was obstructed by gravel bars and by one rock bar known as Big Bend Shoals. The minimum available low-water depth was about 1 foot at Big Bend Shoals. This entire reach was navigable by light-draft boats at all times and the low-water period being of shorter duration than on the upper reaches of the river, the larger boats could operate for all except a few days in the year.

50. *Existing projects.*—(a) The existing project between Florence and the head of Colbert Shoals provides for securing by dredging and contracting works a channel 150 feet wide and 6 feet deep at ordinary

low water, or 5 feet at extreme low water. The extreme fluctuation varies from about 30 feet at the head of Colbert Shoals to 33.3 feet at Florence. The estimated cost, exclusive of amounts expended under previous projects, is \$889,068.17 for new work and \$10,000 annually for maintenance.

(b) The existing project for Colbert Shoals provides for surmounting the shoals by a lateral canal 8.06 miles long (8.7 miles by open river), 112 feet wide at the bottom and 7 feet deep at extreme low water, with a lift lock at the lower end of the canal. The extreme fluctuation in the river varies from about 30 feet at the head to 53.4 feet at the foot of the shoals.

(c) Below Riverton the existing project provides for securing, by dredging, rock excavation, and contraction works, a channel 150 feet wide and 6 feet deep at ordinary low water, or 5 feet at extreme low water. The extreme fluctuation varies from about 49 feet to about 55 feet at different localities. The estimated cost, exclusive of amount expended on previous projects, is \$1,110,000 (first estimated at \$700,-129.71). For the entire stretch from Florence to Paducah fluctuations below extreme high water are so variable that it is impracticable to fix the stage commonly referred to on other streams as ordinary high water.

51. *Present condition.*—(a) From Florence to Colbert Shoals work under the existing project has been completed except that at Tusculumbia Bar during the fiscal year ended June 30, 1919, it was discovered that an error had been made in the year 1918 in establishing the low-water plane during the final operations of sweeping the channel and removing material left above grade by the dredges. A survey of shoals in this section is being made, and until it has been completed the exact depth at low water can not be determined. The total amount expended to June 30, 1920, under the existing project, exclusive of outstanding liabilities and receipts from sales, etc., was \$1,007,414.02.

(b) At Colbert Shoals the lock and canal were completed and placed in operation in November, 1911. The total amount expended for construction was \$2,313,000; and for operation since the canal was opened for use, \$151,274.57.

(c) Below Riverton the available low-water depth had been increased to 3½ feet. This section of the river is usually navigable for 4-foot draft throughout the year, for 5-foot draft from December 1 to September 1, and for 6-foot draft from December 15 to August 15. Four-foot navigation is possible when the Florence gage reads -0.5. For each 0.6 foot on this gage, 1 additional foot of navigable depth is available below Riverton. The total amount expended under the present project was, at the end of the fiscal year 1919, \$774,979.22 for new work and \$4,024.91 for maintenance.

52. The principal existing terminal facilities between Florence and Paducah consist of two railroad inclines extending to near low water; a privately owned wharf boat with superintendent, and a municipally-owned paved wharf with wharfmaster in charge, at Paducah, Ky.; a reinforced concrete warehouse with railway connection and with two vertical elevators and a railroad incline owned by the Louisville & Nashville Railroad Co., at Danville, Tenn.; a frame warehouse with railway connection and with vertical lift elevators, owned by the

Nashville, Chattanooga & St. Louis Railroad Co., at Johnsonville, Tenn.; a privately owned wharf boat at Clifton, Tenn.; a warehouse connected with Southern Railway tracks and with double-track tram-car incline extending to low water, owned by Southern Railway, at Riverton, Ala.; and a railroad incline extending to low water owned by Southern Railway Co., at Sheffield, Ala. It is reported that the warehouses and their mechanical appliances at Danville, Johnsonville and Riverton are open only to the St. Louis & Tennessee River Packet Co., which is the only packet boat line of importance operating on this section of the river. The other facilities mentioned are reported to be open to all boats on fair and equal terms. The city of Sheffield owns an unimproved wharf. There are about 280 unimportant landings where the amount of business done is not sufficient to warrant any improvement. A number of these landings, however, are equipped with small warehouses or sheds. The facilities at Paducah, Danville, Johnsonville, Clifton, and Riverton are fairly satisfactory. The St. Louis & Tennessee River Packet Co. interchanges freight on through bills of lading at all of these places, except Clifton. Other facilities on the lower Tennessee are very unsatisfactory and little interest has been shown in recent years in their improvement.

53. No water powers have been developed in this section of the river. There are three possible sites for power dams—one at the head of Colbert Shoals where a dam might be built to develop power and also to back the water to the foot of Dam No. 2 at Muscle Shoals; another at the foot of Colbert Shoals to overcome the fall of 24.95 feet over that shoal; and the third at the foot of Big Bend Shoals to back the water to Colbert Shoals. No steps have been taken to develop any of these possibilities.

54. High-grade, sedimentary clays, such as are used for electric insulators, porcelain, chinaware, optical glass, pots, graphite crucibles, and sanitary ware, are found in western Tennessee, and they compare favorably with foreign clays and are at present sent north by rail for manufacture. Most of the deposits lie 20 miles or more from the Tennessee River and at present it is not profitable to haul them to the river for shipment. Sand of a quality suitable for use in the manufacture of plate glass, as well as porcelain, is abundant in western Tennessee, but its present market is not large. About 200,000 tons of chert used for road surfacing and railroad ballast is shipped from this region annually. It would appear that more of this could be shipped by water with profit than is now the case. White phosphate and brown iron ores are mined in this region and could, presumably, be shipped by river to a greater extent than is now the case if better highways existed between the mines and the river. In the past the manufacture of charcoal iron was of some importance along the banks of the river in this section, but this industry seems now to have largely died out. The mineral resources of this section of the Tennessee River are of minor value as compared with those in the remainder of the drainage basin. (See Charts I to IV, inclusive.)

55. All of the cities and towns on the river in this section lie well above flood plain except Paducah, and its problem of protection pertains more to floods in the Ohio than to floods of the Tennessee River. However, the fertile river and creek bottom lands in this

section are subject to overflow during the season of growing crops and their protection against such floods would be an advantage. The lands are not of sufficient extent in proportion to the length of the stream affecting them to warrant the construction of levees.

CLINCH RIVER AND TRIBUTARIES.

56. The Clinch River is formed by the junction of its North and South Forks in Tazewell County, southwest Virginia, and flows in a southwesterly direction for about 332 miles, 139 of which are in Virginia, to Kingston, Tenn., where it empties into the Tennessee River, 103½ miles above Chattanooga. The currents and slopes are generally excessive at the shoals but moderate in the pools. The average width between banks, which are usually steep and stable and about 15 feet high, is about 300 feet. There are very few islands, and the bed of the stream at shoals is generally of limestone rock formation, gravel and sand being seldom found. The upper reaches of the river lie in the mountains of southwest Virginia and northeast Tennessee, and in these reaches it is nothing less than a mountain torrent. The drainage basin covers an area of about 4,420 square miles, over which there is a mean annual rainfall of from 48 to 59 inches. The extreme low water discharge at the mouth is about 600 cubic feet per second, while the maximum flood discharges are estimated to be as high as 125,000 cubic feet per second. The principal tributaries are the Powell and Emory Rivers, the former entering the main stream about 88 miles above the mouth and the latter about 4 miles above the mouth.

57. The Federal Government first became interested in the improvement of this stream in 1875, when Maj. Walter McFarland made an examination from the mouth of Indian Creek in Tazewell County, Va., to the mouth of the main stream of the Powell River from the "three forks" in Wise County, Va., to its mouth, and of the Emory River from Bartons Landing (now Webster, Tenn.) to its mouth. The result of these examinations was a recommendation by Major McFarland that improvements be confined to obtaining low water navigation on the Clinch and Powell Rivers by breaking off the points of rocky ledges, blasting and removing large boulders, deepening the channel over some bars, removing fish traps, milldams, snags and overhanging trees, and building a few wing dams at an estimated cost of \$44,025 for Clinch River and \$25,000 for Powell River. For Emory River he recommended against the proposed construction of a wing dam in the Clinch just below the mouth of the Emory, in conjunction with channel improvements on the Emory, on the ground that the public interest did not demand it at that time. In 1881 Maj. W. R. King made an examination of the Clinch from Walkers Ferry, Tenn., up to Nashs Ford in Virginia, a distance of about 161 miles. The report of this examination was favorable to removing all obstructions to low-water mark and to building wing dams wherever necessary at an estimated cost of \$24,510. In 1892 Lieut. John Biddle made an examination of the Clinch River from Clinton to its mouth, as a result of which he estimated the cost of obtaining a low-water depth of 2 feet at \$100,000. In this same year Lieutenant Biddle also made a preliminary examination of the Emory River from its mouth to Harriman, as a result of which he recommended that a survey be made from Emory Gap to the mouth,

for which an estimate of \$600 was made. A survey was made in 1896 by Capt. Dan C. Kingman, evidently in accordance with the recommendation of Lieutenant Biddle, which resulted in a report to the effect that an improvement for low-water navigation of the Emory would be valueless unless extended to the mouth of the Clinch. He therefore favored a lock and dam to be constructed across the Clinch at Kingston to raise the low-water surface 12 feet, at an estimated cost of \$260,000, which would give perfect low-water navigation to Harriman on the Emory and effect an improvement on the Clinch for a distance of 20 or 25 miles upstream. (See Annual Report of the Chief of Engineers for 1897, p. 2318.) This recommendation was not approved by the division engineer, Col. J. W. Barlow, nor the Chief of Engineers, on the ground that the improvement should be deferred until after constant navigation was obtained in the Tennessee River. In June and July, 1899, a survey was made of the Clinch River by Maj. Dan C. Kingman from the Knoxville and Cumberland Gap Railroad bridge, 10 miles above Walkers Ford, to the mouth, a distance of 136 miles. As a result of the survey, Major Kingman, in his report contained in House Document No. 75, Fifty-sixth Congress, second session, favored the improvement of the stream on account of the mineral resources and gave estimates of improvement by various methods for different sections. In 1908 Maj. Wm. W. Harts recommended the suspension of further expenditures until the time should arrive for radical improvement, in view of the slight use made of the stream above Kingston. In November, 1910, an examination was made by Maj. Wm. W. Harts from St. Paul, Va., to the mouth for the purpose of determining where available funds should be expended to best advantage. The result was that it was decided to spend the money on improvements at Clinton Island Shoals, near Clinton, Tenn. In January, 1914, Capt. J. J. Bain made an inspection of the river from Clinton to the mouth and recommended an appropriation of \$2,000 to be used in removing snags in order to facilitate the movements of log rafts. On May 26, 1915, Maj. H. Burgess made a report recommending abandonment of the existing project of improvement by open-channel methods, in view of unsatisfactory results, and substituting therefor a maintenance program of snagging once in every four years at a cost of about \$1,000 per year.

58. Between 1830 and 1845 the State of Tennessee spent certain sums of money, the exact amounts of which are unknown, in improving this river, and in 1845 the State spent an additional \$10,000. The work done by the State consisted in the removal of bowlders, snags, reefs, and overhanging trees and the construction of a few wing dams, with the result that little permanent benefit was derived, it being necessary later to remove some of the wing dams. In 1872 the Legislature of Virginia granted a charter to the Clinch River Improvement Co., which later expended \$1,000 on that portion of the stream lying in Virginia. The Government first expended money on this river in 1880, when \$10,000 was appropriated, \$6,000 of which was required to be spent above Walkers Ferry. In 1910 the Government appropriated \$7,000 for the Clinch River, \$2,000 of which was required to be spent in Virginia. However, under authority of act of Congress of July 25, 1912, the \$2,000 appropriated for Virginia was spent in Tennessee. The entire \$7,000 was spent at

Clinton Island Shoals, just above Clinton, Tenn., between 1911 and 1914. Following is a list of appropriations and allotments for this river:

June 14, 1880.....	\$10,000.00
Mar. 3, 1881.....	3,000.00
Aug. 2, 1882.....	3,000.00
July 5, 1884.....	5,000.00
Aug. 5, 1886.....	5,000.00
Aug. 11, 1888.....	5,000.00
Sept. 19, 1890.....	4,000.00
July 13, 1892.....	4,000.00
Aug. 18, 1894.....	2,500.00
Mar. 3, 1899.....	8,500.00
June 13, 1902.....	3,000.00
Mar. 3, 1905.....	1,500.00
Mar. 2, 1907.....	325.43
June 25, 1910.....	7,000.00
Total.....	61,825.43

Of the above total \$3 was transferred to other works under authority of the river and harbor act of March 4, 1915, and there was an unexpended balance of \$560.97 on July 1, 1920, leaving a total of \$61,261.46 expended by the Government.

59. Clinton, Tenn., 60 miles above the mouth of Clinch, and Webster, Tenn., $7\frac{1}{2}$ miles above the mouth of the Emory, may be considered the heads of steamboat navigation on the Clinch and Emory Rivers. No steamboat navigation is practicable on the Powell River. Small steamboats have been known to ascend the Clinch and Emory Rivers in times of medium and high river stages, but in recent years steamboat navigation is almost wholly confined to that portion of the river below Kingston, Tenn., which is less than a mile above the mouth. Inasmuch as Tennessee River boats have Kingston as one of their landings, the traffic on the Clinch up to that point may properly be classed as Tennessee River traffic. The downstream movement of flatboats and rafts of logs and timber products from the vicinity of Speers Ferry, Va., to the mouth is practicable during high-water periods. The maximum controlled depths at low, mean, and high water are about 1 foot, 2 feet, and 46 feet in the vicinity of Clinton, Tenn., and 2 feet, 3 feet, and 45 feet, respectively, in the vicinity of Kingston, Tenn., and the maximum water surface fluctuation for the reach between Clinton and Kingston is about 45 feet.

60. In Table 13 is a list of bridges with vertical and horizontal clearances at low water.

TABLE 13.—*Bridges across Clinch River and tributaries.*

Location.	Vertical clearance.	Horizontal clearance.	Location.	Vertical clearance.	Horizontal clearance.
Clinch River:	<i>Feet.</i>	<i>Feet.</i>	Clinch River—Continued.	<i>Feet.</i>	<i>Feet.</i>
Massengales Ferry, Tenn.....	39	152	Kiser, Va.....	23.5	68
Kingston, Tenn.....	76	172	Moore's Ferry, Tenn.....	45.8	2'3
Dossett, Tenn.....	56.75	170	Clinton, Tenn.....	48.5	213
Clinton, Tenn.....	53.7	128	Edgemoor, Tenn.....	37.5	213
Lone Mountain, Tenn.....	38	116	Emory River:		
Clinchport, Va.....	35.5	108	Harriman, Tenn.....	57.5	84
Starnes Bend, Va.....	33	82	Do.....	69.2	210
Mile Point 55.3, Va.....	29	64	Do.....	55.3	58
St. Paul, Va.....	25	44	Powell River: Agee, Tenn....	43.2	121

61. Table 14 gives the total commerce handled on Clinch River, including iron ore, sand, stone, timber and farm products, and merchandise. The prospective commerce for this river and tributaries is very large, in view of the enormous deposits of coal and iron and zinc ores in the region which the river traverses. In addition, the river valley along the lower reaches is very fertile, and great quantities of hay, grain, etc., are produced yearly. There are no railroad lines paralleling the river, and this condition would tend to make the river the natural carrier for both mineral and farm products if uninterrupted navigation were practicable.

TABLE 14.—*Commercial statistics of Clinch River.*

Year.	Amount.	Value.	Year.	Amount.	Value.
	<i>Short tons.</i>			<i>Short tons.</i>	
1900.....	132,511	\$1,462,295	1910.....	18,385	\$114,000
1901.....	164,586	1,633,104	1911.....	24,895	192,020
1902.....	129,925	2,272,348	1912.....	27,571	237,758
1903.....	161,716	2,847,373	1913.....	23,294	173,280
1904.....	100,701	1,930,686	1914.....	23,180	243,766
1905.....	126,800	4,733,303	1915.....	(1)	(1)
1906.....	112,284	2,161,130	1916.....	(1)	(1)
1907.....	94,655	1,552,950	1917.....	2,152	96,854
1908.....	65,310	395,460	1918.....	(1)	(1)
1909.....	35,685	216,200			

¹ Figures for 1915, 1916, and 1918 not available.

62. There are no terminals of importance on this river or its tributaries, those which exist being, except in the case of the one at Kingston, Tenn., at best simply graded banks with small warehouses at top of bank. At Kingston there is a good graded bank, unpaved, with a fair warehouse at the top. Except at Kingston, there is perhaps no present need for improvement in terminal facilities.

63. There are at present no water-power developments of importance on this system of waterways. In 1912 a corporation was formed which had a bill introduced in Congress to secure the right to build a power dam on the Clinch River. The bill failed to pass, and so far as known nothing further has been done in this matter. The drainage basin of the Clinch is large and greatly elongated. The river valley is sparsely settled and has no railroad in it except along its upper reaches. The river is comparatively narrow and flows through a rocky formation which seems to be well adapted to the building of high power dams. It has been generally accepted that there are excellent hydroelectric possibilities on the Clinch and Powell Rivers and perhaps on the Emory River (see Chart VI), although no surveys have been made to settle this matter definitely. The possibilities in this river basin are discussed more in detail in Appendix B.

64. The Powell and Emory Rivers drain a country rich in coal and red iron ore deposits. Coal is mined extensively near the headwaters of the Powell in Virginia and in the Cumberland Plateau, whose escarpment forms the west side of the Powell River Valley for its entire length. The Emory River drains a country underlain by coal measures. Coke is manufactured in the basin of the Emory River and near the mouth of the Powell. Red iron ore is exposed in considerable quantities in the basin of the Powell. Brown iron ore is found in the upper part of the basin in Virginia. Lead and zinc are

also found in this region. Marble is exposed in a long belt in this basin on the south side of the Clinch River. Barite and manganese are also found in this basin.

65. So far as is known at the present time, there are no questions of land reclamation or flood prevention on this river with which this report should deal, although floods in this stream have an important bearing on those in the Tennessee River.

HOLSTON RIVER AND TRIBUTARIES.

66. The Holston River is formed by the junction of its North and South Forks at Rotherwood, Tenn., near Kingsport, thence flows in a general southwesterly direction for a distance of $141\frac{1}{2}$ miles and finally unites with the French Broad River about $4\frac{1}{2}$ miles above Knoxville, to form the Tennessee. The width of river varies from about 400 to 600 feet, the variations being rather sudden, the wider points being at the shoals. The channel is well fixed and the banks and bed of stream stable. The changes in depth are usually sudden, long and comparatively deep pools alternating with shoals formed by ledges of rock, the strata of which are inclined usually at a considerable angle pointing upstream. Islands are few in number and the many bends are seldom sharp or long. The total low-water fall from Kingsport, Tenn., to the mouth is 360 feet, an average fall of 2.55 feet per mile; 289 feet, or 80 per cent of the total fall is concentrated at the shoals which cover a distance of 36 miles, or 25 per cent of the total length. This fall occurs at 104 places (shoals), which vary in length from 150 feet to over 2 miles, where the depth is less than 2 feet. The low-water discharge at the mouth is about 700 cubic feet per second and floods discharge as much as 175,000 cubic feet per second. The headwaters of this river have their origin in southwestern Virginia and find their way to the main stream through the North and South Forks. The total drainage area of the system is about 3,860 square miles, of which approximately two-thirds is on the forks. The mean annual rainfall varies from 41 to 59 inches. The distinguishing characteristics of this basin are the frequent occurrence of small closed basins or sinks and springs, and small streams which disappear underground and sometimes reappear on the surface.

67. Col. S. H. Long, Corps of Topographical Engineers, United States Army, made the first examination of this river for the Government in 1830, the State of Tennessee cooperating in that work. The examination covered not only what is now known as the Holston River but also that portion of the Tennessee River from the present mouth of Holston to the mouth of the Little Tennessee River, 51 miles in length. As a result of this examination, the State of Tennessee did some improvement work in the nature of removal of boulders and other obstructions from the channel and construction of spur and longitudinal dams in 1830 and later. (Annual Report of Chief of Engineers for 1901, p. 2525.) In December, 1880, an examination was made by Maj. W. R. King, including the North Fork of the Holston from Saltville, Va., to its mouth, and the Holston proper from the "forks" down to Noeton, Tenn., 72.8 miles. The report of this examination, which was published in House Executive Document No. 77, Forty-sixth Congress, third session, proposed the

removal of old, unnecessary dams, snags, and other obstructions, and the construction of a few wing dams, in order to provide safe downstream navigation for flatboats in the North Fork, at a total estimated cost of \$115,148, and work of a similar nature, though somewhat more extensive, to provide a low-water depth of 16 inches over a channel width of 60 to 80 feet for steamboat navigation, for the Holston River, at an estimated cost of \$127,765. In 1886 the examination of this river was resumed by Col. J. W. Barlow and was completed from Noeton, Tenn., to Knoxville, Tenn., $4\frac{1}{2}$ miles below the mouth of the Holston, a total distance of 69.7 miles. The report of this examination, which was printed in the Annual Report of the Chief of Engineers for 1887, pages 1772 to 1775, contemplated the removal of channel obstructions and the construction of suitable dams and training walls with a view to obtaining a low-water depth of 20 inches over a channel width of 90 to 140 feet from Noeton, Tenn., to Knoxville. Colonel Barlow recommended an appropriation of \$347,000, to be expended entirely on the Holston from Kingsport, Tenn., to Knoxville, Tenn. In November and December, 1899, a survey was made of the Holston River from Kingsport to the mouth by Maj. Dan C. Kingman, and this survey was made the subject of a report in the Annual Report of the Chief of Engineers for 1901, pages 2518 to 2541, and in House Document No. 218, Fifty-sixth Congress, second session. Major Kingman's recommendation was that no work of improvement be undertaken at that time, except the removal of channel obstructions, and the cutting of overhanging trees at an estimated cost of \$5,000, inasmuch as complete regulation for a navigable depth of $2\frac{1}{2}$ feet would cost at least \$750,000 and improvement by locks and dams would cost about \$4,080,000, and such large expenditures were not then justified.

68. About the year 1830 the State of Tennessee did considerable improvement work on this stream, consisting of removal of channel obstructions and the construction of spur and longitudinal riprap dams. No record of cost of this work is available. In June, 1902, Congress appropriated \$5,000 for the removal of channel obstructions and the cutting of overhanging trees, and again in 1907 an additional allotment was made. All of the above money, except \$303.26, which was returned to the Treasury, was applied to clearing channel obstructions and cutting overhanging trees. In 1908 all work was stopped and nothing has since been done.

69. There is no regular upstream navigation of the river, though occasionally a small steamboat runs 30 to 60 miles above the mouth at times of high water. Downstream movement of rafts of logs and flatboats of small draft is possible during about nine months in the year. The maximum controlled depths at low, mean, and high water are about 1 foot, 2 feet, and 42 feet, respectively, and the maximum water surface fluctuation is about 41 feet.

70. In Table 15 is given a list of bridges with vertical and horizontal clearances at low water:

TABLE 15.—*Bridges across Holston River and tributaries.*

Location.	Vertical clearance.	Horizontal clearance.	Location.	Vertical clearance.	Horizontal clearance.
South Fork of Holston River, Kingsport, Tenn.....	<i>Feet.</i> 57	<i>Feet.</i> 113	Holston proper—Continued.	<i>Feet.</i>	<i>Feet.</i>
North Fork of Holston River, Kingsport, Tenn.....	55	109	Rogersville, Tenn.....	50	121
Holston proper:			Chisolms Ford, Tenn.....	36	140
Brabsons Ferry, Tenn....	59	116	Surgoinsville, Tenn.....	36	95
Boyd's Ferry, Tenn.....	64.5	187	Church Hill, Tenn.....	36	192
Strawberry Plains, Tenn.	50	106	Davis Ferry, Tenn.....	40	145
Morristown, Tenn.....	49	115	Turley Ferry, Tenn.....	35	130
Rogersville, Tenn.....	36	197	Shields Ferry, Tenn.....	36.5	127
			Crocketts Ferry, Tenn....	38	197.5

71. Following is the only available record of traffic on this river:

Logs and lumber:	Short tons.
1902.....	9, 136
1903.....	15, 501
1904.....	12, 249
1905.....	11, 912
1906.....	19, 800
1907.....	12, 240

In addition to the above there were 242 short tons of other commodities, including grain, tiling, scrap iron, etc., handled in 1903. As to prospective commerce, it may be said that in the region which this river traverses, marble and raw materials from which cement is made abound and that, in addition, farm products in the valley are important. The river is a natural outlet for all farm products and for such minerals as occur on the lower reaches.

72. There are no terminals of any kind on this river, the unimproved bank serving the purpose throughout, and there is no present need for improvement of these facilities.

73. The only waterpower development of importance now in operation on the Holston River system is that of the Watauga Power Co. on the Watauga River, a tributary of the South Fork of the Holston, 18 miles south of Bristol, Tenn., shown as No. 3 on Chart V. This development, which is of 3,200 horsepower, transmits its power to Bristol, where an auxiliary steam plant is located. The topography of this basin suggests the possibility of a considerable hydroelectric development in this region but no maps or other data exist which permit this subject to be thoroughly canvassed. A discussion of the possibilities here as they appear to-day is given in Appendix B.

74. Salt and gypsum deposits are extensively worked on the headwaters of the North Fork of the Holston River near Saltville, Va. Marble beds are exposed along the North Fork of the Holston near Gate City, Va., and also along the river east of Knoxville. Zinc is extensively mined near Mascot, Knox County, over 25,000 tons having been mined there in 1919. Some lead is obtained as a by-product of smelting zinc ores. Manganese and brown iron ore deposits are found in the Watauga Basin. Low-grade phosphate rock is found there but is not mined at present. About 60,000 tons of magnetite is mined annually in the upper Watauga Basin. In this basin granite of commercial value is also abundant, but is at present undeveloped. Barite occurs along the Middle Fork of the Holston.

75. So far as is known at the present time, there are no special questions of land reclamation or flood prevention on this river with which this report should deal. It should suffice to say that in any study of improvement by locks and dams for navigation or any study of water power development, the question of the probable effect of such works during times of floods would then be one of paramount importance.

FRENCH BROAD RIVER.

76. The French Broad River is one of the principal tributaries of the Tennessee, and by its junction with the Holston in east Tennessee forms that river. The head of the French Broad is in Transylvania County, N. C., where its north and west forks unite and form the main stream. From this junction it flows in a northeasterly direction, then northwesterly, through the North Carolina counties of Transylvania, Henderson, Buncombe, and Madison for about 102 miles before it crosses into Tennessee. The portion of the river within Tennessee flows in a generally westerly direction through the counties of Cooke, Jefferson, Sevier, and Knox for about 102 miles to its junction with the Holston, $4\frac{1}{2}$ miles upstream from Knoxville, Tenn. The entire basin of the French Broad is about 5,130 square miles, with a length of approximately 100 miles and a maximum width of about 90 miles. The mean annual rainfall in this basin varies from 40 to 66 inches, and is fairly uniformly distributed throughout the year, with a greater rainfall, however, in the late winter and spring months. The river is essentially a low-water stream, but has occasional floods during the winter and spring. The minimum discharge at the mouth is approximately 1,200 cubic feet per second, and its maximum about 150,000 cubic feet per second. No discharge measurements have actually been taken at the mouth, and these figures are estimates from observations elsewhere. The principal tributaries of the French Broad are the Big Pigeon, Nolichucky, and the Little Pigeon, of which only the latter enters the French Broad in that part which has been under improvement by the Federal Government.

77. The river is naturally divided by physical conditions into three sections: First, that from the forks to Asheville, N. C., about 60 miles in length, with a fairly moderate low-water slope and not impracticable for improvement for light-draft traffic by open-channel methods. Second, the section from Asheville to the mouth of the Nolichucky, in Cooke County, Tenn., a total distance of 74 miles, of which 42 miles is in North Carolina and 32 in Tennessee. This section has all the characteristics of a mountain torrent, having a total fall in 74 miles of nearly 1,000 feet and being wholly impracticable for navigable improvement, except by canalization—a most expensive method of improvement by reason of the great number of locks and dams necessary for the purpose. This section is a complete barrier for navigation between the navigable section in North Carolina, formerly under improvement, and the navigable section in Tennessee. Third, the section from the mouth of the Nolichucky to the junction of the French Broad and the Holston, a distance of 71 miles. This section is the only part of the stream which has been covered by an instrumental survey. Leadvale, Tenn., where the Southern Railway crosses the stream, is about 1 mile below the mouth of the Nolichucky, and has for convenience been regarded as the head of this

navigable portion of the French Broad, although the change in the character of the stream is at the mouth of the Nolichucky rather than at Leadvale. The 69½ miles of river below Leadvale is described in somewhat more detail by the following quotation from the report of March 27, 1900, as given on pages 3019 et seq., report of the Chief of Engineers for 1900:

This part of the river has a width varying from 300 to 1,200 feet, with an average of about 600 feet; its banks are generally low, averaging about 15 feet above low water, and are subject to overflow in time of freshets. The banks are generally composed of a stiff resisting clay, and, as a rule, do not appear to be subject to erosion. The bottom of the river is of sand, gravel, and rock in the deeper portions and generally of solid rock or coarse gravel and boulders on the shoals. The valley of the river is broad and fertile and is quite generally cleared and under cultivation. * * *

The river is generally free from sand bars, though small gravel bars are sometimes found in the sheltered portions about the islands; but the indications are that only a small amount of detritus is transported by the water, and this is largely derived from the tributaries.

The mean fall of the river from Leadvale to the mouth is 2.32 feet per mile. The surface of the water is broken into the usual number of pools and rapids. The pools, however, are generally quite short, averaging only about 2 miles each, and the longest is only about 6 miles.

The maps show 41 localities where the low-water channel is less than 3 feet deep or where the fall is so great that navigation is practically impossible at low water. The aggregate length of the obstructions is about 20 miles, and upon this 20 miles more than 80 per cent of the fall is concentrated. The maps show that as a rule a low-water depth of about 2 feet has been secured by the work already done, although in some places the line of deepest water is so crooked that it can not be fully utilized. There are 12 shoals, however, where the available depth is less than 2 feet.

78. The Federal Government first interested itself in the improvement of this stream in 1830, when the first examination was made under the direction of Col. S. H. Long, topographical engineer. As a result of this examination the State of Tennessee, about 1835, made certain improvements in the river channel, consisting largely of the removal of snags and boulders and the construction of riprap spur dikes, which did not produce permanent results. In 1870 an examination was made by Lieut. M. B. Adams under the direction of Maj. Godfrey Weitzel, covering that portion of the river below the mouth of the Nolichucky, as a result of which it was proposed to provide a navigable depth of not less than 2½ feet from the mouth to Dandridge, at an estimated cost of \$150,000. The section above Dandridge was not considered worthy of improvement. (See Annual Report of the Chief of Engineers for 1871, pp. 491 to 494.) The river and harbor act of June 23, 1874, authorized an examination of the French Broad River from Brevard, N. C., to the Henderson-Buncombe County line. The report of this examination is contained in the report of the Chief of Engineers for 1875, part 1, page 817 et seq. The river and harbor act of March 3, 1875, authorized the continuing of the survey from the Henderson-Buncombe County line to the mouth.

A report of this survey and examination is contained in the report of the Chief of Engineers for 1876, part 1, page 718 et seq. From July to September, 1877, a survey of the river from Brevard to Asheville was made, and upon that survey three projects for improvement between Brevard and Big Buck Shoals, (1) by locks and dams, (2) by lateral dams, (3) by short wing dams and groins, were prepared. The report is contained in Annual Report of the Chief of Engineers for 1878, part 1, page 522 et seq. The recommendation was favor-

able to the method of improvement by groins, short wing dams, and excavation, at an estimated cost of \$125,000. In 1876, Major McFarland recommended that plans be revised so as to extend the improvements up to Leadvale, Tenn. In 1900, Maj. Dan C. Kingman submitted a report based on survey of 1899, authorized by act of Congress of March 3, 1899, between Leadvale and the mouth and including the Little Pigeon River, in which he estimated the cost of improvement by canalization (20 locks and dams) would cost not less than \$2,000,000 and recommended improvement by regulation. The division engineer, Col. Henry M. Roberts, concurred, expressing the opinion that the river was worthy of improvement from its mouth to the mouth of the Nolichucky to the extent of obtaining a 3-foot navigable depth at a cost of \$280,000. The river and harbor act of June 25, 1910, authorized a preliminary examination of the river in North Carolina, and the report of this examination, which was unfavorable, is contained in House Document No. 1071, Sixty-second Congress, third session. The river and harbor act of March 4, 1915, authorized a reexamination of French Broad River, Tenn., with a view to modification or abandonment of the improvement project and the report of this reexamination, which recommended abandonment of project, is contained in House Document No. 489, Sixty-fourth Congress, first session. The river and harbor act of June 5, 1920, authorized a preliminary examination of this river in North Carolina and the district engineer's report of this examination, which has not been printed, was made on October 13, 1920. The report recommended that further action in the matter be deferred until it can be taken as a part of the general survey of the Tennessee River authorized by the river and harbor act of June 5, 1920. The report was returned to the district engineer by the Chief of Engineers with instructions to make appropriate report to cover this item coincident with report on Tennessee River and tributaries called for by the above act.

79. The earliest appropriations of record made for this river by the Federal Government were made between 1876 and 1882, and their total was \$43,000. This provided for open-channel work in North Carolina. Between 1877 and 1885 this money was expended but so far as known, little, if any, benefit was derived therefrom. No further appropriations have been made for this section. The existing project was adopted by the river and harbor act of June 14, 1880, and provides for securing by dredging, by contraction works, and by removal of surface obstruction a channel $2\frac{1}{2}$ feet deep during the low-water season from Leadvale to the mouth ($69\frac{1}{2}$ miles) and for the removal of the bar at the mouth of the Little Pigeon River. Under this project the following appropriations have been made:

June 14, 1880.....	\$10,000	June 13, 1902.....	\$15,000
Mar. 3, 1881.....	3,500	Mar. 3, 1905.....	2,000
Aug. 2, 1882.....	5,000	Mar. 2, 1907.....	2,000
July 5, 1884.....	3,500	Mar. 3, 1909.....	5,000
Aug. 5, 1886.....	6,000	June 25, 1910.....	23,000
Aug. 11, 1888.....	10,000	July 25, 1912.....	15,000
Sept. 19, 1890.....	10,000	Mar. 4, 1913.....	15,000
July 13, 1892.....	15,000	Oct. 2, 1914.....	10,000
Aug. 18, 1894.....	7,000	Mar. 4, 1915.....	30,000
June 3, 1896.....	5,000		
Mar. 3, 1899.....	5,000	Total.....	197,000

Practically all of the money appropriated as listed above has been expended below Dandridge, 26 miles above mouth, with the result that the project depth has been obtained from Dandridge to Huffaker Shoals, 11 miles from the mouth, except for a small amount of work at Fox Island and Seven Island Shoals, and the condition of the river below Huffaker Shoals has been improved. The work as a whole below Dandridge is about 70 per cent completed.

80. In its present condition the river may be considered as navigable for 2½-foot draft up to Dandridge for about 8 or 9 months of the year, and from Dandridge up to Leadvale for about 5 months of the year. However, steamboats rarely go above Dandridge. Above Leadvale navigation is not practicable, except perhaps for the downstream movement of rafted timber products. The maximum controlled depths at low, mean, and high water below Dandridge are about 1½ feet, 3 feet, and 30 feet, respectively; between Dandridge and Leadvale, 1 foot, 2 feet, and 25 feet; and above Leadvale, ½ foot, 1 foot, and 20 feet, the water surface fluctuation being about 20 feet at Asheville, N. C., 25 feet at Dandridge, and 30 feet at the mouth.

81. Above Leadvale, Tenn., there are some 15 or 20 bridges spanning the stream, about half being of steel construction and half of timber. They have a vertical clearance of from 12 to 25 feet above low water and a horizontal clearance of from 50 to 100 feet. On the navigable portion of the river below Leadvale there are two bridges, one at Leadvale and one at Dandridge. These have vertical clearances of 30 and 57 feet above low water and horizontal clearances of 151 and 177 feet, respectively.

82. The section of the river from its source to Asheville has carried a small amount of commerce local in character, and the section between Asheville and Leadvale has no doubt carried a certain amount of timber products in rafts, but no detailed record in either case is available. The section below Leadvale is the one where steamboats have operated and where most of the commerce has existed. In the section below Leadvale most of the freight has been handled below Dandridge, as boats plying this section have Dandridge on the French Broad and Knoxville on the Tennessee as their terminals. The principal items transported on this river have been marble and farm products, the former class originating from quarries along the river, and the latter from farms in the river valley. Table 16 shows the freight in short tons handled during recent years, exclusive of marble:

TABLE 16.—*Commercial statistics of French Broad River.*

Short tons.		Short tons.		Short tons	
1890.....	27, 877	1900.....	49, 751	1910.....	11, 375
1891.....	22, 248	1901.....	16, 590	1911.....	15, 760
1892.....	19, 705	1902.....	21, 709	1912.....	12, 935
1893.....	17, 425	1903.....	38, 826	1913.....	8, 072
1894.....	49, 398	1904.....	27, 247	1914.....	2, 618
1895.....	42, 898	1905.....	40, 200	1915.....	8, 866
1896.....	159, 804	1906.....	24, 407	1916.....	5, 836
1897.....	42, 256	1907.....	15, 319	1917.....	129, 701
1898.....	48, 210	1908.....	10, 170	1918.....	4, 231
1899.....	22, 263	1909.....	8, 440	1919.....	1, 720

The quantity of marble transported has shown a marked decrease in recent years, due, it is believed, to the diversion of this commodity to railway lines in this region. The record shows the tonnage of

marble handled in 1904 as 159,600 and in 1914 as 11,475. As to prospective commerce it may be said that the river is the natural highway for the transportation of all farm products in the rich river valley, which is not adequately served by railways, and for marble, sand, and iron ore, all of which are found in this region.

83. There are no efficient terminals or terminals of appropriate and suitable types and construction on this river, such facilities as exist being simply landings with small warehouses at top of bank at some places.

84. Aside from several mills utilizing water power, there are on the French Broad River and tributaries near Asheville (see No. 2, Chart V) at present in operation four hydroelectric plants doing a public service business. These operate without pondage and have a combined installed capacity of 8,250 horsepower. On the Noli-chucky River is a plant which has a 39-foot dam with foundation suitable for 70-foot dam (see No. 1, Chart V). It has an installed capacity of 3,600 horsepower and an ultimate capacity of 16,000 horsepower. The former plants, in connection with which a steam auxiliary plant of 3,500 horsepower capacity is operated, are owned by the North Carolina Electrical Power Co., and the latter, in connection with which a steam auxiliary plant of 1,800 horsepower is operated, is owned by the Tennessee Eastern Electric Co. Between Leadvale and the mouth of the river the topography is such that two power dams could be built (Nos. 11 and 12, Chart VI), making available the fall of about 120 feet, if dam sites could be found and flowage damages permit. In 1908 the French Broad River Power Co. contemplated a development at a point a short distance above the mouth of the Holston River, but their project did not materialize. From Leadvale to Asheville the river is paralleled at a low level by a railroad. There is a fall of about 1,000 feet in this distance which makes a large power development potentially available. To become actually available it would be necessary either to relocate the railroad or to build low diversion dams with long flumes. The power so made available would be quite small during the low-water season if no storage is provided, but above Asheville the topography seems to lend itself to storage on a large scale. Foundation conditions and extent of flowage for such storage works are at present unknown. On the Big Pigeon River there is a total fall of about 1,200 feet in 50 miles, above which there lies a considerable drainage area. The river valley is often narrow and deep and seems to be well adapted to power development. Flowage damages should be low. No special information is available as to the adequacy of dam sites. It is reported that a company has recently been formed to develop the entire power of this river and tributaries, and that plans for this development have been worked out in detail. It is said that the total output will eventually reach 200,000 horsepower. On the Noli-chucky River two or three additional power dams have been suggested, and the topography seems to be favorable. No information of value is at hand on the subjects of dam sites or flowage damages. Some small power development has been suggested on the Little Pigeon River concerning which no details are available. The location of the town of Sevierville seems to interfere with any extensive project.

85. Some brown iron ore occurs in the basin of this river and has been used in connection with the magnetite of the adjacent Watauga Valley to the north. Zinc is mined at Embreeville on the Nolichucky River and manganese is found in the basin of the Nolichucky. Bauxite was mined to some extent during the war. The slate deposits on the headwaters of the Little Pigeon River are believed to be of value, but have not as yet been developed. Granite of commercial value is abundant in this basin, but has never been developed. Kaolinite or china clay is mined and sent to pottery manufacturers in the North. Barite is abundant in this region and has been mined. Other minerals of less importance are found in this basin and are mentioned more in detail in Appendix C.

86. As to land drainage and reclamation, a problem is presented on this river in the region above Asheville in the general vicinity of Brevard and Hendersonville, N. C., where the river banks are very low and where the river frequently does much damage to crops by overflow. It is in this section of the river that the Government between 1877 and 1885 expended about \$40,000 in the construction of spur and wing dams in the interest of navigation. These works, it is claimed by residents of this region, have restricted the area of river channel and thus caused overflows to be more frequent and banks to cave in and wash away. The condition appears to be one which should properly receive careful consideration in connection with the river system as a whole. The section of the river in the vicinity of and above Asheville has been visited by several severe floods, the last and possibly the most disastrous of which occurred in July, 1916, when the river rose to about 21 feet at Asheville, destroying and damaging much property, including dams, bridges, industrial plants, etc. These floods extend, of course, throughout the length of the river, but apparently do not cause as great loss on the lower as on the upper reaches, though the damage to crops, etc., is not inconsequential.

LITTLE TENNESSEE RIVER AND TRIBUTARIES.

87. The Little Tennessee River rises in the Blue Ridge Mountains near Rabun Gap, Rabun County, Ga., flowing thence in a general northerly direction to Franklin, N. C., and thence in a general north-westerly direction to opposite Lenoir City, Tenn., about 47 miles downstream from Knoxville, where it empties into the Tennessee River. It has a length of about 7 miles in Georgia, 80 miles in North Carolina, and 49 miles in Tennessee, a total length of about 136 miles. It cuts through the Great Smoky Mountains and the Chilhowee Mountains before entering the valley along its lower reaches. The fall is very steep from its source to the Chilhowee Mountains, being 1,480 feet in the distance of 109 miles, an average of $13\frac{1}{2}$ feet per mile, but from the latter point to the mouth, 33 miles, the fall is only 80 feet, an average of 2.48 feet per mile. The principal tributaries are the Nantahala, Tuckasegee, Cheoah, and Tellico Rivers, all of which, except the Tellico, which rises in the Unaka Mountains in eastern Tennessee, rise in the mountains in western North Carolina. The upper reaches of the main stream and its tributaries generally have high, steep banks, and the lower reach of

the main stream below McGhee, Tenn., 20 miles above the mouth, has banks varying in height from 12 to 18 feet. The bed of the stream is composed of solid rock, gravel, and loose bowlders. The drainage basin, in which the mean annual rainfall varies at different points from 46 to 82 inches with a mean for the whole basin of about 58 inches, has an area of about 2,650 square miles. This catchment basin furnishes a low water discharge at the mouth of about 900 cubic feet per second, and a maximum flood discharge of about 125,000 cubic feet per second.

88. In 1874 Maj. Walter McFarland made an examination of this river from its mouth to the foot of the Chilhowee Mountains, a distance of 25 miles, as a result of which an estimate of \$55,000 was made providing for a channel 2 feet deep and 40 feet wide from the mouth to Howard's milldam, 19 miles long, but the recommendation was unfavorable to this expenditure. In 1875 this examination was continued up to Rabun Gap, Ga., 109 miles upstream, by Major McFarland, with the result that the recommendation was averse to any improvement above the mouth of Citico Creek. These reports are printed in Annual Reports of the Chief of Engineers for 1875, pages 813 to 817, and 1876, pages 715 to 718. In 1881 Maj. W. R. King made an examination from the mouth to Calloway's ferry, $2\frac{1}{2}$ miles above the mouth of Tellico River, a total distance of $22\frac{1}{2}$ miles, and at this same time the examination was extended up the Tellico River to a point 6 miles above its mouth. As a result of this a recommendation was made (see Annual Report of the Chief of Engineers for 1882, pp. 1871 to 1875) for an expenditure of \$23,724 to provide a low-water depth of 2 feet over a channel width of 40 feet on the Little Tennessee River and \$2,798.40 for clearing out rocks and ledges which obstructed boats descending at a stage of 2 feet. In 1899 Maj. Dan C. Kingman made an examination from the mouth to the slate quarries on Abrams Creek, and in the same year he made a survey from the mouth to Silver Creek, a distance of 39.2 miles. The report is contained in House Document No. 66, Fifty-sixth Congress, second session. Major Kingman's recommendation provided for improvement by regulation from the mouth of the river to the mouth of Silver Creek in order to obtain a navigable low-water channel $2\frac{1}{2}$ feet deep of ample width, at an estimated cost of \$208,505. In 1918 Assistant Engineer W. S. Winn made an examination pursuant to the provisions of the river and harbor act of August 8, 1917, of that portion of the river lying in Tennessee, as a result of which he recommended that the river be not improved at that time, nor until the improvement of the main trunk stream, the Tennessee, had progressed to such an extent as would warrant attention being diverted to its tributaries. (See House Document No. 1126, 65th Cong. 2d sess.)

89. In 1882 Congress made an appropriation of \$5,000 to be applied to the project of securing a channel 2 feet deep and 40 feet wide, between the mouth and Calloway's ferry, by regulation methods. These funds were expended by December, 1883. In February, 1906, and again in March, 1907, \$1,000 was allotted for maintenance on this river, of which \$1,489.91 was later returned to the Tennessee River project, the remainder being spent.

90. Steamboats have navigated this river during high-water periods as far upstream as Stratton Shoals, 36 miles above the mouth,

and have also gone a few miles up the Tellico. However, it may be said that the river is not ordinarily navigable, except for downstream movement of rafted timber products, for more than a very few miles above its mouth, where small gasoline boats sometimes engage in transporting farm products from the valley to terminals on the Tennessee River. The maximum controlled depths at low, mean, and high water for the section below McGhee, Tenn., are about 1 foot, 2 feet, and 39 feet, the water surface having a fluctuation of about 38 feet.

91. In Table 17 is a list of bridges on the Little Tennessee and tributaries, the vertical and horizontal clearances at low water being given in each case.

TABLE 17.—*Bridges across Little Tennessee River and tributaries.*

Location.	Vertical clearance.	Horizontal clearance.
LITTLE TENNESSEE RIVER.		
McGhee, Tenn.	Feet. 46.1	Feet. 115
Indian Rock, Tenn.	47	217
TELLICO RIVER.		
Vonore, Tenn.	21.5	95
Do.	21	52

92. No records of commercial statistics are available for this river, the same having no doubt been included in the records for the Tennessee River, as such commerce is largely common to both streams. In general, the commerce on the Little Tennessee has consisted principally of timber and its products carried in rafts and flatboats downstream and general merchandise and farm products carried in rafts and small steam and gasoline boats both up and down stream on the lower reach. The quantity of river freight transported in recent years is comparatively small and is probably diminishing. As to prospective commerce, there are deposits of slate, manganese, barite, and marble in the basin between the Chilhowee Mountains and the mouth of the river. These minerals, when developed, should largely find their way out by water when dependable navigation obtains. Farm products from the lower valley ought also to go by water route to their markets.

93. There are no terminals of importance on this river, the bare river bank affording the only facilities for handling river traffic between boat and land. There is no present need for improvement of existing facilities.

94. It is on this river that is found the most extensive water-power development yet projected in the Tennessee River Basin. Of this development a power dam with an effective head of 190 feet has been built across the Little Tennessee River, just above the Cheoah River, having a present installation capable of delivering 72,000 horsepower, and capable of extension to nearly 100,000 horsepower. In addition to this, the project calls for another dam on the Little Tennessee with an effective head of 209 feet and a capacity of over 100,000 horsepower; a third with an effective head of 172 feet, and a maximum capacity of 80,000 horsepower; a fourth with an effective head of 210 feet, and a maximum capacity of about 40,000 horsepower; and a fifth with an effective head of 260 feet and a maximum

capacity of 36,000 horsepower. On the Cheoah River it is proposed to build a dam giving an effective head of 590 feet, and a maximum capacity of 45,000 horsepower. On the Nantahala River an effective head of 825 feet gives a maximum capacity of about 35,000 horsepower. Two smaller installations on the Nantahala River and Yalaka Creek give an added capacity of about 30,000 horsepower. The approximate location of these nine sites are shown on Chart VI, Nos. 36-43, inclusive. This gives a total installed capacity of about 460,000 horsepower. It is expected that about 350,000 horsepower continuous output will be obtained. This comprehensive project provides for the eventual development of practically all the potential hydroelectric power available in this basin. Only minor installations are omitted and it is probable that their use will not be of commercial value for some time. The eventual completion of this project promises to have a marked influence on the industrial future on this part of the Tennessee River Basin, and there is reason to believe that there are other streams tributary to the Tennessee on which hydroelectric developments comparable to this lie within the limits of possibility. Of the properties in the basin of the Little Tennessee which make this development possible, those in the State of Tennessee are owned by the Knoxville Power Co. and those in North Carolina are owned by the Tallassee Power Co., both of which are subsidiary companies of the Aluminum Co. of America.

95. Undeveloped slate beds are exposed along the lower course of the Little Tennessee River below the hydroelectric developments above mentioned. The southern extension of the Knoxville marble district crosses the Little Tennessee River at its mouth. Manganese deposits are found near these marble belts. Some brown iron ore and manganese occur near the Tellico River. Some other minerals of secondary importance in this valley are mentioned in Appendix C.

96. Questions of land reclamation and flood flow are not of special importance on this river. It is to be expected that the completion of the system of power dams referred to above will tend to effect a material equalization of the Little Tennessee River. This would probably increase appreciably the low-water flow and perhaps cause perceptible diminution in the flood stages of the Little Tennessee proper.

RICHLAND RIVER.

97. Richland River, also known as "Richland Creek" and "Big Richland Creek," rises on Waldens Ridge in Bledsoe County, Tenn., and flows in a general southeasterly direction for a distance of about 22 miles, entering Tennessee River about 40 miles above Chattanooga. It is a very small stream, hardly large enough to be termed a river. The town of Dayton is situated on this stream 4.36 miles above the mouth. The fall from Dayton to the mouth is 36.7 feet, giving a mean rate of 8.4 feet per mile. Above Dayton the rate of fall is much greater. The discharge at low water is about 15 cubic feet per second from a total drainage area of about 80 square miles.

98. In August, 1899, an examination of this stream was made by Maj. Dan C. Kingman as a result of which an estimate of \$150,000 was made for two locks below the mouth of Little Richland Creek, each to have a lift of 9 feet. The recommendation was unfavorable to making the improvement, in view of the insignificance

of the stream, its excessive slope, its small discharge, and the comparatively few industries. (See Annual Report of the Chief of Engineers for 1900, p. 3075.) In 1907, pursuant to authority contained in the river and harbor act of March 2, 1907, Maj. William W. Harts made a preliminary examination, resulting in a report printed in House Document No. 223, Sixtieth Congress, first session, unfavorable to any improvement at that time.

99. The only available record of work done on this stream is contained in Annual Report of the Chief of Engineers for 1907, page 1622. The work was done under authority of the Secretary of War during the fiscal year 1907 and consisted in dredging at the mouth, the cost of which was paid by the Dayton Coal & Iron Co., Dayton Tenn.; 3,100 cubic yards of soft material and the timbers from two old sunken barges were removed.

100. This stream is not navigable for boats except for a few hundred feet above the mouth at medium and high stages, as a shoal occurs at the mouth. The maximum controlled depth between Dayton, Tenn., and the mouth at low, mean, and high water is about 3 inches, 1 foot, and 12 feet, respectively, the water surface fluctuation being about 12 feet.

101. There is no commerce on this stream and there is no prospect of any in the future. The Dayton Coal & Iron Co., of Dayton, Tenn., owns a railroad which connects with their coal mines and iron furnace near Dayton and the mouth of the river, the same paralleling the river most of the way. This road was used in past years for transporting iron ore brought to the mouth of river on barges from the mines on the Tennessee River to the furnace and for hauling coal from the mines to the river, where it was loaded on barges for shipment by river. The furnaces have been closed for a number of years and coal shipments have been practically discontinued by water. Any future resumption of this rail and water route will probably find the iron ore and coal being handled from a terminal on the Tennessee River, near the mouth of Richland River, instead of from a terminal on Richland River. There is no record of the amounts of commerce handled on this stream.

102. The only terminal on this river is at a point about 200 feet above the mouth, where there is a landing with a railroad on top of the bank. There are no mechanical facilities for transferring freight from river to rail.

103. There are no water-power developments on this river and, so far as is known, there are no possibilities of any important development in the future.

104. Coal is the only mineral deposit of any importance known to exist in this region. The principal industry of this section is that of coal mining.

105. There are no questions of land reclamation or flood prevention which should have attention on this river.

HIWASSEE RIVER AND TRIBUTARIES.

106. The Hiwassee River rises in northwestern Georgia near Unicoi Gap, Towne County, in the Blue Ridge Mountains, and flows in a general northwesterly direction for about 127 miles, passing through the western part of North Carolina and into Tennessee, and entering the Tennessee River about 36 miles above Chattanooga.

Its lengths in Georgia, North Carolina, and Tennessee are 16, 51, and 60 miles, respectively. The fall from its source to Savannah Ford, 85½ miles, is about 1,800 feet, an average of about 21 feet per mile, and its fall from Savannah Ford to its mouth, 41½ miles, is about 52 feet, an average of about 1¼ feet per mile. Its principal tributaries are Valley River, Nottely River, and Ocoee River, the first of which has its source in western North Carolina, and the other two in northern Georgia. The upper portion of the catchment basin of this system is very rugged and mountainous, but the lower portion of the main stream, that below Savannah Ford near the mouth of the Ocoee River, passes down a valley with wide reaches of fertile bottom land on either side. The total area of the basin is about 2,720 square miles; the mean annual rainfall at various points therein varies from 51 inches to 65 inches with a mean for the entire area of about 57 inches; and the low water discharge at the mouth is about 1,000 cubic feet per second. Flood discharges reach 147,000 cubic feet per second. From the foot of Gamble Shoals, near the mouth of the Ocoee River, 36 miles, the width of river varies from about 200 to about 400 feet, the banks of which have an average height of about 15 feet. The bed and banks are stable, the bed at shoals being composed of solid rock, hard gravel, and bowlders, and in the pools of gravel and sand, and the banks being composed largely of clay which is not subject to excessive scour.

107. In 1874, Maj. Walter McFarland made an examination of this river from its mouth to Savannah Ford, a distance of 41.6 miles, and as a result his report made the same year contained an estimate of \$20,000 for obtaining a low-water depth of 2 feet over a channel 40 feet wide. In 1892, Col. Henry M. Robert made a preliminary examination of the river from its mouth up to the mouth of the Ocoee, the report on which was favorable to making a survey from the mouth to Savannah Ford, on the ground that the river was worthy of improvement. In 1899 a survey was made in conformity with the recommendations of Colonel Robert, Maj. Dan C. Kingman being the officer in charge. This survey was the subject of a report by Major Kingman in September, 1900, in which plans and estimates of cost of the open-channel work necessary were contained. Major Kingman expressed the view that the river was worthy of improvement from its mouth to the mouth of Ocoee River for 30-inch depth, at a cost of \$71,125. In June, 1915, Maj. H. Burgess made a report on this river in which he recommended that the Hiwassee River be dropped from the list of streams under improvement by the United States, in view of the smallness of the commerce and of the slight prospects for material increase therein, but that occasional snagging be done out of funds provided for maintenance and improvement of the Upper Tennessee River.

108. In November, 1881, Maj. W. R. King made a preliminary examination for a canal to connect the headwaters of the Hiwassee and Tennessee Rivers with those of the Savannah River. Two routes were examined, both commencing at the junction of the Tallulah and Chattooga Rivers which unite to form Tugaloo River, which in turn is a tributary of Savannah River. From this point the first route of examination was carried up Tallulah River and Dicks Creek to Hightower Gap, and thence down Hightower Creek to Hiwassee River. The other route was up Chattooga River and Sticoa Creek to

Rabun Gap, and thence down Little Tennessee River to Franklin, N. C. This examination was made the basis of a report submitted in January, 1881, and published in Chief of Engineers Annual Report, 1881, page 1888. As to the relative merits of the two routes, it was found that on the score of practicability and economy of construction and operation, the advantage lay with the Rabun Gap route. A tunnel and feed reservoirs would be necessary for the Hightower route but neither of these would be necessary for the Rabun Gap route. On the other hand, the Hightower Gap route was found to be the most direct. The distance by water from Augusta, Ga., to Chattanooga, Tenn., by the Rabun Gap route, would be 701 miles, while by the Hightower Gap route it would be 608 miles. Major King expressed the opinion "there is but one serious engineering question in regard to the feasibility of this transportation route, viz., the question of lockage." He recommended that an appropriation be made for a survey which he estimated would not cost more than \$15,000. Apparently nothing further was ever done in regard to this matter. Between 1830 and 1842 the State of Tennessee expended certain sums, the exact amounts of which are unknown, on the improvement of this stream, but the work done was of little permanent value.

109. The original Government project for the improvement of this river, based on the examination made in 1874, was adopted by the river and harbor act of August 14, 1876, and provided for a low-water channel depth of 2 feet, 40 feet wide from Savannah Ford to mouth, to be obtained by open-channel work, at an estimated cost of \$20,000, which estimate was increased in 1878 to \$30,000, in 1882 to \$34,000, and in 1885 to \$36,500. The river and harbor act of June 13, 1902, adopted a new project, which is the one now existing, contemplating the improvement of the river between its mouth and the mouth of the Ocoee River by open-channel work to secure a 3-foot depth at ordinary low water in the boat channel and a mean depth of 2½ feet throughout the entire width of navigable channel, which was to be 164 feet, with a minimum of 116 feet on one shoal. The width of dredged channel was to be 50 feet. (See H. Doc. No. 77, 56th Cong., 2d sess.) Under this project \$126,282.40 has been appropriated or allotted to date, of which \$123,065.71 has been expended, with the result that about half the work proposed has been completed. Following is a list showing appropriations to date for previous projects. (See H. Doc. No. 1491, 63d Cong., 3d sess., p. 464.)

June 13, 1902.....	\$10,000.00
Mar. 3, 1905.....	4,500.00
Mar. 2, 1907.....	55,282.40
Mar. 3, 1909.....	5,000.00
June 25, 1910.....	10,000.00
July 25, 1912.....	5,000.00
	<hr/>
	89,782.40
For present project.....	36,500.00
	<hr/>
Total appropriations.....	126,282.40
Transferred to other works, river and harbor act of Mar. 4, 1907.....	3,216.69
	<hr/>
Net total of appropriations.....	123,065.71

110. Steamboat navigation at low and mean river stages is practically limited to the section between Charleston, Tenn., and the

mouth, 19 miles, where the larger portion of improvement work has been done, although it is possible for steamboats to ascend as high as Savannah Ford, 41.6 miles above the mouth, at medium or high river stages. Navigation above Charleston is hindered, however, by the Southern Railway bridge across the river at that point which has a headroom above low water of only 35.8 feet and above high water of only 3 feet. It is practicable for light steamboats and gasoline boats to operate the year round between Charleston and the mouth and for larger boats to operate during about eight months of the year. The maximum controlled depths at low, mean, and high water below Charleston are about 2 feet, 3 feet, and 35 feet, the water surface fluctuation being about 34 feet.

111. Following is a list of bridges across this river, vertical and horizontal clearances being given in each case:

Location.	Vertical clearance.	Horizontal clearance.
	<i>Feet.</i>	<i>Feet.</i>
Charleston, Tenn.....	35.8	175
Do.....	37.5	116
Patty, Tenn.....	44.3	115
Just above mouth of Ocoee River, Tenn.....	47.6	125
Near Patty, Tenn.....	38	156

112. The drafts of the boats which have recently operated on this river vary from 15 inches to 3 feet. Until very recent years one or more large packet boats operated between the mouth and Charleston, connecting with Tennessee River boats at the mouth or having Chattanooga on the Tennessee River as their home port. In addition, small gasoline boats operated through most of the year. However, at the present time only one or two small gasoline boats operate and these without any regularity, the result being that river traffic has greatly diminished. In Table 18 are shown commercial statistics for this river.

TABLE 18.—Commercial statistics of Hiwassee River.

Year.	Forest products.	Farm products.	Merchandise and miscellaneous.	Total.	Rafted.	Total carried by boat or barge.	Passengers.
	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	
1902.....	9,444	3,055	2,042	14,541	6,014	8,527	638
1903.....	7,099	5,713	740	13,532	6,266	7,286	975
1904.....	1,857	816	330	3,003	1,380	1,623	260
1905.....	5,878	1,880	3,117	10,875	4,649	6,226	67
1906.....	1,730	1,138	695	3,563	¹ 1,300	¹ 2,263	200
1907.....	2,645	3,070	1,325	7,040	¹ 2,400	¹ 4,640	360
1908.....	3,510	2,346	474	6,330	¹ 3,400	¹ 2,930	124
1909.....	400	2,160	460	3,020	¹ 200	¹ 2,820	.....
1910.....	833	1,704	541	3,078	¹ 500	¹ 2,578	.....
1911.....	1,871	1,539	307	3,717	971	2,746	.....
1912.....	1,831	1,808	473	4,112	458	3,654	.....
1913.....	1,699	720	220	2,639	399	2,240	.....
1914.....	1,208	436	698	2,342	570	1,772	1,225
1915 ^a.....	.....	.....	.....	.....	.....	.....	.....
1916.....	³ 132	³ 336	.....	.....	.....	.....	.....
1917.....	1,051	657	444	2,152	.....	.....	.....
1918.....	³ 8,376	³ 635	.....	.....	.....	.....	.....
1919.....	.....	506	.....	.....	.....	.....	.....

¹ Estimated; reports not complete.

² None reported.

³ All reported; may not be complete.

As to prospective commerce on the lower reach of the Hiwassee, iron ore, manganese, and lead deposits of some importance occur, and the river valley produces large quantities of grain. These products should eventually find their way to market at Chattanooga or elsewhere by river.

113. There are no terminals of importance on this river, the ungraded bank, without warehouse, in most cases, affording the only means of transferring between boat and bank. There is at present no need for improving existing facilities.

114. Next to the hydroelectric developments on the Little Tennessee River, those owned by the Tennessee Power Co. on the Ocoee, a tributary of the Hiwassee, are the most important installations of any on the tributaries of the Tennessee River. Here there are now in operation two plants, one near Parksville having an installed capacity of 25,000 horsepower, the other about 8 miles above with an installed capacity of 20,000 horsepower. (See Chart V, No. 5.) The completed project of this company calls for two additional power dams on this river, which, combined, will give an additional head of nearly 400 feet. These, with the existing development, will make the eventual capacity of the system about 90,000 horsepower. When completed, this system will utilize all the power available on this stream. In addition to the above, the Tennessee Power Co. now leases the bulk of the power generated at the Hales Bar Dam, and this, together with some power generated outside of the basin of the Tennessee River, is widely distributed and used throughout eastern Tennessee by various public utilities and private industries. On the Hiwassee River above the mouth of the Ocoee there exist four promising power-dam sites. The rights to two of these sites are now the subject of litigation between two power companies. It is supposed that when these legal difficulties are adjusted additional developments in this region will be begun. The amount of power available at these four sites is greater than that found on the Ocoee River but has not been accurately estimated. It is believed that the completion of these developments on the two streams will materially improve the stream flow conditions on the lower Hiwassee River, increasing the low-water and decreasing the high-water flows.

115. In this basin at Ducktown, Tenn., is found one of the most important copper-mining centers of this part of the United States. In connection with the smelting of these copper sulphide ores sulphuric acid is produced, and here is also found the largest sulphuric-acid plant in the United States. In 1919 the production of copper at this place was valued at \$2,538,703 and that of sulphuric acid was \$2,468,598. Iron sulphide (pyrite) is mined with the copper sulphide, and the two ores are smelted simultaneously in the manufacture of sulphuric acid and pure copper. About \$50,000 worth of gold and silver is obtained annually as a by-product in the course of the above operations. Red and brown iron ores are found in this basin. Marble, talc, and soapstone occur in the general vicinity of Murphy, and these have assumed moderate commercial importance. The manganese and barite deposits of this basin have been mined but have not yet attained prominence. Corundum and lead have been located, but as yet have not been extensively exploited. Quartz has been mined near Murphy.

116. The questions of land reclamation and flood prevention on this river and tributaries are not of pressing importance.

SEQUATCHIE RIVER.

117. Sequatchie River rises in the southern part of Cumberland County, Tenn., near the town of Burke, and flows in a general south-westerly direction about 80 miles, wholly in the State of Tennessee, entering the Tennessee River about 3 miles above the town of South Pittsburg. It has a width ranging from about 30 feet in its upper portion to 150 feet or more at its mouth. It is generally supposed to be a continuance of Lost Creek, which, flowing northward on the northern side of the divide, sinks into a subterranean passage, thence flows back southward underneath the divide, finally emerging as the source of Sequatchie River. The stream is somewhat tortuous, skirting rocky hills in many places on one side or the other, at which places the river channel is constricted in width and depth and the bed rocky. The river is obstructed by rock and gravel shoals, and in some places islands occur, making the channel exceedingly narrow. The banks are for the most part low and are composed principally of alluvial soil or sand, but fairly stable. The average depth of the river channel is about 3 feet. The drainage basin covers an area of about 610 square miles. No figures giving the discharge of the river are available.

118. In 1892 Col. Henry M. Robert submitted a report on a preliminary examination of this river, in which he expressed the opinion that it was not worthy of improvement. (See Annual Report of the Chief of Engineers for 1893.)

119. In 1838 the State of Tennessee appropriated \$5,000 for the improvement of this river, but no record of what was done with these funds obtains. The Government has never done any work on the stream.

120. In the early part of the nineteenth century, about the year 1830, this river was used extensively for downstream movement of farm products by flatboats and timber products by rafts, but so far as is known steamboats have never navigated the river. The maximum controlled depths at low, mean, and high water are about 6 inches, 1 foot, and 20 feet, respectively.

121. There is no record of commercial statistics available for this river. At present there is no commerce on the river, neither is there any prospective commerce of any importance.

122. There are no terminals on the stream.

123. Except for several low milldams, there are no water-power developments on this river. Two power dams have been suggested—one on the main stream and one on the Little Sequatchie. These, if practicable, would be of secondary importance only. (See Chart VI, Nos. 49 and 50.)

124. Coal is extensively mined in near-by horizontal beds occurring at elevations of about 800 or 900 feet above the valley floor. In 1919 about \$2,000,000 worth of coal was mined either in the southwestern part of this basin or in territory immediately adjacent to it across the divide. Red iron ore has been mined in the lower valley, but of late there has been little activity in this direction. About 40,000 barrels of lime are manufactured annually in the upper part of the basin.

125. The questions of land reclamation and flood prevention do not enter into consideration on this river.

GUNTERS CREEK.

126. Gunters Creek, called Big Spring Creek on the United States Geological Survey map, is a small stream which rises near Brooksville, Ala., and flows in a northeasterly course for a distance of about 23 miles, entering Tennessee River at the town of Guntersville. Its valley is long, straight, narrow, and of uniform width.

127. In 1890 Col. J. W. Barlow made an examination of this stream at the mouth with a view of ascertaining the practicability and approximate cost of so improving the same as to secure a safe landing above high-water mark. The report of this examination, which was published in the Annual Report of the Chief of Engineers for 1891, page 2326, was unfavorable to improvement being made by the Government. No other examinations have been made, and no improvement work has ever been done by the Government on this creek. There has never been any navigation on this stream.

128. As far as is known, there are no water-power developments on this stream and the possibilities for such development in the future are limited. Coal and perhaps iron ore are the only minerals occurring in appreciable quantities in the region drained by this stream. There are no land-reclamation or flood-prevention considerations of importance needing attention at this time.

PAINT ROCK RIVER.

129. Paint Rock River is formed in Jackson County, Ala., by the junction of the Larkin and Estill Forks, both of which have their sources in Franklin County, Tenn. It flows in a direction a little west of southerly for a distance of about 65 miles and enters the Tennessee River 15 miles below Guntersville and 38 miles above Decatur, Ala. The lower 12 miles have a general westerly course and an unusual uniformity of width, being about 60 feet wide at low water, with a minimum width of 40 feet. The fall in this 12 miles is about 7 feet, giving an average fall of nearly 0.6 foot per mile. This portion is more or less obstructed by snags and by overhanging timber. There are also a number of obstructing reefs or shoals, the most serious one being of rock with very little water over it at low stages. The drainage basin has an area of about 507 square miles.

130. Only one examination of this river has been made by the Government and that one was in 1913 by Maj. H. Burgess. The purpose of the examination was to ascertain the advisability of improvements to facilitate the movement of freight between New Hope, Ala., about 8 miles above the mouth, and Hobbs Island, on the Tennessee River, 6 miles below the mouth of Paint Rock River. The examination was extended 4 miles above New Hope. The report of this examination, which is printed in House Document No. 227, Sixty-third Congress, first session, was unfavorable to improvement at that time. There is no record of any improvement work having been done on this stream.

131. Navigation of this river by small boats is possible between the mouth and New Hope, Ala. There is one bridge with a vertical clearance at low water of 18 feet and a horizontal clearance of 35 feet at low water, which is at New Hope, Ala., on the lower reach of this stream. There is little or no commerce on this stream, and the

prospect for an increase is not bright at the present time. There are no terminals of importance on the stream.

132. As far as is known, there are no water-power developments on this stream, and none have ever been seriously considered. Coal is the principal mineral occurring in the area drained by this river. Land reclamation and flood prevention do not seem to be of special importance on this stream.

ELK RIVER.

133. Elk River rises in Grundy County, Tenn., on the western slope of the Cumberland Mountains. It flows in a southwesterly direction and finally enters the Tennessee River between Decatur and Florence, Ala., and about 30 miles above the latter place. The total length of the river from Fayetteville, Tenn. (head of possible navigation), to its mouth is 90 miles, of which 56 miles is in the State of Tennessee and 34 miles in the State of Alabama. The average width at low water below Fayetteville, Tenn., varies from about 125 feet in the upper portion to about 300 feet at the mouth. The width of the portion above Fayetteville is much less. The aggregate fall of that portion below Fayetteville is 131 feet, which gives a mean fall of 1.45 feet per mile. The mean slope is quite uniform, decreasing slightly toward the mouth. The bottom of the channel is generally gravel overlying rock, which outcrops at various places. It consists of a succession of pools separated every few miles by shoals of rock or gravel, where the fall is concentrated and the width often not more than 50 feet at low water. The bedrock in many places has been found to be of horizontal stratification. The banks range from 15 to 25 feet in height and have an average slope of about 2 feet horizontal to 1 foot vertical. The drainage area of this stream is about 2,000 square miles, over which there is a mean annual rainfall of about 54 inches. The low-water flow at the mouth is in the neighborhood of 130 cubic feet per second and flood discharge as high as 60,000 cubic feet per second.

134. In 1884 a preliminary examination was made of this river by Maj. W. R. King, and the resulting report, printed in Annual Report of the Chief of Engineers for 1885, page 1771, was unfavorable to improvement. In 1890 a survey was made covering the section between Fayetteville, Tenn., and the mouth, but before the survey was completed Maj. Dan C. Kingman, in charge of survey, was called upon for a preliminary report. This report, published in House Document No. 147, Fifty-fifth Congress, third session, recommended that about \$4,000 be appropriated for the purpose of removing fish traps, snags, leaning trees, and other channel obstructions in the lower 35 miles of river and doing away with the bar at the mouth. The final report of survey was made in 1899, and is published in House Document No. 87, Fifty-sixth Congress, in which the opinion is expressed that it would be impossible to provide navigation for small steamboats as far up as Fayetteville by any system of open-channel work and that it would cost \$882,854.61 to secure 4-foot navigation by use of locks and dams. In 1902 Maj. John G. D. Knight submitted a preliminary examination report covering the section below Fayetteville, Tenn., which was unfavorable to improvement. In 1907 Maj. William W. Harts made a preliminary examina-

tion report for the river below Fayetteville which was also unfavorable to improvement. (See H. Doc. No. 951, 60th Cong., 1st sess.)

135. The river and harbor act of March 3, 1899, appropriated \$4,000, which was spent in open-channel work along the lower reaches of the river. No further work was done.

136. At low water steamboat navigation on the river is obstructed by insufficient depths and at high water by bridges which lack sufficient clearance. Steamboat navigation is practically limited to the lower 13 miles of the stream, due to the low bridge at Elk River Mills, although Fayetteville, Tenn., has been regarded as the head of possible navigation. There are a number of bridges across the stream along the lower reaches, but all that is known in regard to them is that they are very low, affording insufficient vertical clearance for steamboats.

137. There is practically no commerce on this stream at present and no prospective commerce is now in sight.

138. There are no improved terminals on this river and none appear to be needed at present.

139. There are two water-power developments on this river—one, that of the Public Light & Power Co., of Chattanooga, Tenn., having a 550-horsepower installation at Winchester, Tenn., and the other, that of the Fayetteville Electric Light & Power Co., a 100-horsepower plant at Fayetteville, Tenn. The former plant is connected with the Hales Bar plant on the Tennessee River.

140. Some coal is mined in the upper end of this basin and about 20,000 tons of coke were produced in this region in 1919. Phosphate rock is mined in the western central part of the basin in moderate amounts. Marble deposits, apparently worthy of development, are found not far from Fayetteville. Limestone, shale, and sand of commercial value have been located in this basin.

141. There are no questions of land reclamation or flood prevention which need consideration on this river.

BEAR CREEK.

142. Bear Creek, also known as "Big Bear Creek" or "Bear River," rises in northwest Alabama and flows in a circuitous course first in a general westerly direction to the Alabama-Mississippi State line and thence in a general northerly direction, meandering back and forth across the State line to a point near Eastport Landing, Miss., where it enters the Tennessee River. Its total length is approximately 80 miles. This stream is naturally divided by physiographic conditions into two sections, the upper one extending from the source to Southards Ford, a distance of about 50 miles, and the lower section from Southards Ford to the mouth, a distance of about 30 miles. The upper section has a much steeper slope than the lower, and the channel bed, especially at the Shoals, is of rock formation. The fall from Southards Ford to the mouth of Big Crippled Deer Creek is 21 feet in a distance of about 6 miles, or a mean fall of 3.5 per mile. The total fall from the mouth of Big Crippled Deer Creek to the mouth of Bear Creek is 44 feet in a distance of about 24 miles, giving a mean rate of 1.8 feet per mile. There are numerous sharp bends and shoals, principally of gravel formation. The circuitous course, especially of the lower portion, is shown by the fact that the distance

along the stream from the Southern (formerly the Memphis & Charleston) Railroad bridge to the mouth is about 18 miles, while by a direct line it is only about 8 miles. The stream is subject to sudden rise and fall. The banks are generally low and composed of a sandy loam easily washed out. Sloughs, small swamps, and cut-offs are numerous and the channel variable, especially in the lower section. At the bends the channel is generally obstructed by deposits of soil, gravel, willows, etc.

143. In 1875 Maj. Walter McFarland made a report on an examination of the feasibility of connecting the Tennessee River and the Tombigbee River by a canal by way of Bear Creek. The result of this examination, the report of which is printed in Annual Report of the Chief of Engineers for 1875, pages 803 to 809, was unfavorable on the ground that the expenditure necessary was not warranted at that time. In 1881 an examination was made from the mouth for a distance of 30 miles upstream by Maj. W. R. King, resulting in a report which estimated the cost of open-channel work necessary to facilitate the descent of flatboats at \$5,900, and stated that the character of the stream precluded low or slack water navigation at any reasonable cost. (See Annual Report of the Chief of Engineers for 1882, pp. 1869-1871.) In 1887 a preliminary survey was made by Col. J. W. Barlow, extending from Southards Ford to the mouth, 30 miles, and in addition a reconnaissance was made from the ford to a point about 5 miles upstream. The report, which is contained in Annual Report of the Chief of Engineers for 1888, pages 1639 to 1641, gave two estimates, one of \$50,000 for open-channel work and the other of \$500,000 for slack-water navigation providing 3-foot depth. Colonel Barlow gave it as his opinion that this stream was worthy of improvement.

144. There is no record of any improvement work being done on this stream. This stream is not navigable for steamboats, but downstream movement of rafts and flatboats is possible during favorable stages. There is now little or no commerce transported on this creek and there is none in prospect at this time. There are no terminals of any importance in existence on Bear Creek.

145. As far as is known, there are no water-power developments on this creek and the possibilities of such development are limited. The mineral and industrial resources of this region are not worthy of special mention. There are no questions of land reclamation or flood prevention requiring consideration at this time.

BEECH RIVER.

146. Beech River is a small unimportant creek rising in Henderson County, Tenn., near Lexington, flowing southeasterly through Henderson and Decatur Counties, and emptying into the Tennessee River near Perryville, Tenn., about 135 miles above Paducah, Ky. The elevation of low water at the railroad bridge near Lexington is reported by the railroad company to be 415 feet. The elevation of low water in the Tennessee River at Perryville is 323 feet. The fall is thus seen to be 92 feet. The entire length of the stream is about 185 miles, and the average fall is probably much less than 1 foot per mile, especially in the lower reaches, where it is very flat. Its drainage basin covers an area of approximately 270 square miles, and its

low-water discharge is estimated at not to exceed 50 cubic feet per second at the mouth. Its average low-water width in the lower portion, where it is affected by back water from the Tennessee River, varies from about 30 to 100 feet, and in shoal places the depth of water is often but a few inches. Its course is very winding, as evidenced by the fact that occasionally bends are found where the distance across by land is but a mile or two, whereas by river the distance is perhaps a half a day's journey by skiff. It flows through a rolling country, much of which is unimproved. The main obstructions are the sharp bends and snags.

147. An examination of this stream was made in October, 1907, by Maj. William W. Harts, House Document No. 58, Sixtieth Congress, first session, page 3. He gave it as his opinion that this river was not worthy of improvement at that time. No improvement work has ever been done on the stream by the Government.

148. There has never been any navigation on the stream except the rafting of logs, the value of which rafted during 1906 was reported to have been \$15,000. There are no terminals worthy of mention.

149. There are no water-power developments on this stream and there seems to be little possibility of such development in the near future. Phosphate and iron-ore deposits occur near the mouth of this creek.

DUCK RIVER.

150. Duck River rises in the plateau of the Cumberland Mountains near Manchester in Coffee County, Tenn. It flows a little north of west wholly in the State of Tennessee for a distance of about 250 miles, finally entering the Tennessee River about 14 miles above Johnsonville and about 110 miles above the mouth of the latter river. It consists of a succession of fairly deep pools having an average width of about 300 feet, separated every few miles by rock and gravel shoals, where the usual width is not over 100 feet and the depth but a few inches. The stream meanders back and forth across its flood plain, striking rock bluffs on first one side and then the other. The alluvial banks are from 10 to 25 feet high. The bluffs are from 100 to 200 feet high and consist of subcarboniferous limestone and thick strata of dark siliceous rock. Duck River has only one tributary of importance, which is Buffalo Creek, sometimes called Buffalo River. It rises in the northern part of Lawrence County, Tenn., near Summer-town and flows westerly about 32 miles and thence northerly about 40 miles, entering Duck River about 9 miles above the mouth of the latter. The fall from Flatwoods to Standing Rock Ford, in a distance of 47 miles, is 109 feet, giving a mean rate of fall of 2.3 feet per mile. The mean annual rainfall for the river basin is about 50 inches, and the drainage basin area is about 3,640 square miles. The low-water flow at the mouth is about 200 cubic feet per second, and floods discharge as much as 100,000 cubic feet per second.

151. In 1879 an examination of this river was made by Maj. W. R. King from Centerville, Tenn., to its mouth, as a result of which an estimate of \$35,118 was made for improvements to secure low-water depths of $2\frac{1}{2}$ to $3\frac{1}{2}$ feet for four to six months during the year. (See Annual Report of the Chief of Engineers for 1880, pp. 1681-1684.) In 1892 an examination was made by Col. Henry M. Robert,

resulting in a report in which it was recommended that snags and overhanging trees be removed from the mouth up to the foot of Hackle Shoal, a distance of 20 miles. In 1907, Maj. William W. Harts made a preliminary examination of the river from the mouth to Centerville, Tenn., and the report of this examination was unfavorable to the expenditure of money in improvements on the ground that present and prospective commerce did not warrant such. The report is printed in House Document No. 348, Sixtieth Congress, first session.

152. In 1840, 1844, and 1846 the State of Tennessee incorporated private companies to make this river navigable from Columbia, Tenn., to the mouth by means of locks and dams. The last company chartered, "The Duck River Slackwater Navigation Co.," was the only one to do any work, and such work as was done was small and of no value. This company in 1853 was perpetually enjoined by the courts from prosecuting its work further, this being the result of a suit against the company by some of its stockholders. During the years 1880, 1881, and 1882 the Government made appropriations totaling \$13,000 for improving the river to the extent of securing channel depths of $2\frac{1}{2}$ to $3\frac{1}{2}$ feet, but such work as was done was of little permanent benefit to navigation.

153. Steamboats have been known to ascend this river as far as Centerville, 68 miles above the mouth, and have quite frequently been able to go up as far as Hackle Shoal, 25 miles above the mouth. These trips were no doubt made at medium or high stages of the river. In general, the portion above Hackle Shoal is not suitable for navigation except that of downstream movement of rafts and flatboats. The fluctuation of water surface has a maximum of about 45 feet.

154. Following is a list of bridges across this stream, vertical and horizontal clearances being given where known:

Locality.	Vertical clearance.	Horizontal clearance.
	<i>Feet.</i>	<i>Feet.</i>
Cold Branch Ferry, Tenn.....	40	191
Near Link Ford, Tenn.....	40	233
Torsee Ferry, Tenn.....	28	140
Beaver Dam, Tenn.....	36.5	(¹)
Huddleston, Tenn.....	(¹)	(¹)
Centerville, Tenn.....	52.5	137

¹ Not known.

155. In former years a large amount of commerce is said to have been carried on this river, but commercial statistics to show dates and amounts are lacking. However, at the present time little freight of any kind is transported. As to prospective commerce, large deposits of iron ore, phosphate, and limestone suitable for lime, are found in the region which this river drains, and if suitable navigation was obtained much of the raw or finished products might find their way out by water.

156. There are no terminals of any importance on this stream.

157. There are a few hydroelectric plants of from 75 to 200 horsepower capacity. There are said to be three possible sites for power dams in this basin. (See Nos. 51, 52, and 53, Chart VI.)

158. Considerable deposits of brown iron ore are found in the basin of this river. Of five concerns engaged in mining this ore, the largest produces about 40,000 tons per annum. Further increase in this industry is supposed to be possible. Large deposits of phosphate rock occur in this basin. In 1919, 867,283 long tons were mined, which had a value of \$3,594,683. This is the second largest deposit of this character in the United States.

159. So far as is known, land reclamation and flood prevention are not of special importance on this river.

BIG SANDY RIVER.

160. Big Sandy River is a small stream lying wholly within the State of Tennessee. It rises in the northern part of Henderson County and flows in a direction a little east of north for a distance of about 65 miles and enters Tennessee River near the town of Bayne, about 67 miles above Paducah. The distance on a direct line from source to mouth is about 55 miles. Its width varies from 25 to 160 feet. The banks are, as a rule, quite low, averaging about 8 feet above low water. There are occasional bluffs along the river. Pools alternate with shoals of rock and gravel formation. The depth varies from 6 to 18 inches on the shoals and from 3 to 15 feet in the pools. The stream is very tortuous, with numerous sharp bends. It is very much obstructed by snags and to a less degree by sand and gravel bars. The fall in the river is concentrated largely at the obstructions. The fall from Westport to the mouth is 115 feet in about 47 miles, giving a mean rate of nearly $2\frac{1}{2}$ feet per mile. The drainage basin has an average width of about 10 miles and an area of about 550 square miles. No figures of discharge are available.

161. In 1905 Maj. H. C. Newcomer made an examination of this river from Big Sandy to the mouth, a distance of 34 miles, as a result of which an unfavorable report was made in House Document No. 153, Fifty-ninth Congress, first session. In 1907 Maj. William W. Harts made a preliminary examination, and in a report contained in House Document No. 217, Sixtieth Congress, first session, he gave it as his opinion that the river was not worthy of improvement by the Federal Government at that time. There is no record of any improvement work ever having been done on this stream.

162. Steamboat navigation is confined to the lower portion of this stream, where during high-water stages on the Tennessee River it is possible for boats to operate in the backwater. The downstream movement of log rafts at high river stages is practicable. In addition to the obstructions caused by snags and bars there were in 1907 five fish-trap dams and five bridges across the river which were obstructions to navigation. The commerce on this stream is very small and of little importance. There are no terminals on the river.

163. As far as is known there are no water-power developments on this stream. The mineral resources of this region are limited. Farming and lumbering are the principal industries. The questions of land reclamation and flood prevention have no special importance on this river.

GENERAL DISCUSSION.

164. The streams described above are those on which the question of improvement for navigation has at some time been raised. In

addition there are numerous tributaries to the Tennessee River proper or to its larger branches, where mineral or hydroelectric developments may at some future time appear that are of commercial importance. For example, it is supposed that on Town and Sauty Creeks (tributaries of the Tennessee just above Gunter'sville) there are possibilities of hydroelectric development which have attracted some attention and are worthy of future study. Between Chattanooga and the mouth of the Clinch a number of tributaries enter the main stream from the west. Some of these have drainage areas of fair size, and the possibilities of hydroelectric developments there have been suggested, while in the mountains still less is known of some of the secondary streams. No information exists which warrants the mention of individual sites on these rivers, and yet there is a feeling that a comprehensive survey, such as that proposed, would bring to light more than one attractive possibility which would otherwise remain unappreciated.

OBJECTS OF PROPOSED SURVEY.

165. The proposal to make a comprehensive survey of the Tennessee River and its tributaries arises from the belief in the minds of many men who have given this matter careful thought that this basin is rich in undeveloped possibilities industrially and commercially. The industrial future is believed to rest primarily on the large amount of hydroelectric power which is potentially available both on the numerous large streams tributary to the Tennessee, which flow down from the mountains forming the rim of this basin and on the main river itself in its fall of 450 feet in the 430 miles from its source to the foot of Colbert Shoals. Second in importance only to this hydroelectric power, in the minds of these men, are the mineral resources of this region covering a list of some 20 or 30 minerals known to exist in commercial quantities in this region, none of which have been thoroughly developed and only a few, such as coal, iron ore, marble, zinc, etc., appreciably developed. The commercial future depends in large measure on the transportation facilities by which this region is joined to the rest of the country. Of these, it is commonly accepted that existing railroad facilities are now, or soon will be, inadequate and that future extension on their part is not to be expected for many years to come. The Tennessee River and its tributaries are then considered to be the best hope of this region for greater transportation facilities in the immediate future. This river joins the Ohio about 50 miles from the Mississippi, and from here freight-carrying boats can readily reach Cincinnati, Louisville, New Orleans, St. Louis, and, it is hoped in the near future, Chicago. These cities and the area served by them form an important market for the products of the basin of the Tennessee, and from that same area comes an appreciable amount of the raw material used in the local industries.

166. It is therefore the hope of the local interests that the hydroelectric, industrial, and mineral resources of the Tennessee Basin may be rapidly developed and that as these develop the rivers of this region will be found to be in condition to carry freight between this basin and the rest of the valley of the Mississippi. When private interests seek to develop hydroelectric power in the Tennessee River basin it is found here, as elsewhere, that questions arise as to the

effect which the proposed installations will have on the navigable portions of these rivers, not to mention the ever-recurring question of what are the limits of these navigable portions. Furthermore, a large amount of this potential power lies in the Tennessee River itself, an undeniably navigable stream, where, to be made available, this power must be developed by the United States or by other interests who have received from the United States certain definite and acceptable rights and privileges. Certain hydroelectric installations have been made in this basin, both on the tributaries above the head of navigation and on the main river itself, where navigation has also thereby been improved; yet it is felt by local interests that the delays, conditions, and uncertainties connected with such developments have appreciably retarded the growth of this promising industry. It is the hope, then, of these interests that in the course of the proposed survey means will be found, not simply to remove everything in the nature of an obstruction to such progress, but even to facilitate and stimulate such enterprises. Hydroelectric power and native mineral resources suggest manufacturing industries and it seems to be expected that the proposed survey will, furthermore, point out a program of possible development which shall include such locations for the prospective plants as will insure the most efficient use of the navigable river system in its complete state of improvement which it is hoped will ultimately be attained. Finally, it is hoped that the information acquired in the course of the proposed survey will be sufficient in quantity and accuracy to enable prospective investors in power or manufacturing plants to dispense with much of the expensive investigation indispensable in launching undertakings in a comparatively virgin territory.

167. With this conception of the purpose of the proposed survey in mind, the efforts of this office during the short period available for the preliminary examination have been devoted to the assembling of all readily accessible facts which had a bearing on the views and opinions of the local interests. The most important part of this information is presented in condensed form in the preceding paragraphs devoted to the various sections and tributaries of the river and in the appendices to this report. This is again condensed and summarized under the following headings:

GENERAL INDUSTRIAL SITUATION.

168. From the days of the first settlement of this region the chief industries have been agriculture and lumbering and to a lesser degree the quarrying of marble, the mining of coal, iron ore, etc. To serve these industries the rivers of this basin have been considerably improved by the Government and a considerable mileage of railroads has been built throughout this territory, and, broadly speaking, statistics indicate that these transportation facilities were for some time ample for the needs of this vicinity. Of recent years this section has had its share in the increased manufacturing activity which has been growing up in the South, and because of its extensive mineral resources and its unusual possibilities of future hydroelectric development local interests feel confident that this growth can readily be continued and augmented. Growing industries must have a

growing market which must always be within reach through adequate means of transportation. There seems to have been no trouble in finding the necessary markets so far, but during the last three years trouble has arisen here, as elsewhere, due to inadequate transportation facilities. Attention seems, therefore, to be focused upon the Tennessee River system, first, as a source of hydroelectric power to feed a growing manufacturing industry, and second, as a freight-carrying route for the distribution of these manufactured products to suitable markets.

169. The market for power and the tonnage for the river depend in large measure on the number and character of the new industries that may be developed in this region, and an examination of the future possibilities in this direction opens a field of investigation almost limitless in its possibilities. Much time and thought have been spent in the course of the preparation of this report in the effort to prepare a fair statement of conditions as they exist to-day, together with a conservative estimate of what might be expected to follow in this regard from the thorough study proposed for this survey. The result of the efforts in this direction has been the conviction that no fair statement of this character can be prepared in the short time and with the limited resources now at hand. Less is being said, therefore, on this subject than was expected at the outset, and what is said deals more with generalities than has been intended. So far as it has been deemed wise to discuss this matter under existing conditions, it is believed that the statements made will prove, in the light of future studies, to be accurate.

170. Industries in this region may be divided into two classes, (a) those dependent upon local resources and (b) those dependent upon foreign resources, local resources being those found in the Tennessee River Basin or immediately adjacent thereto, and foreign resources being those found outside this area, either in the United States or elsewhere. Of the first class the manufacture of cotton products has been growing in importance for 10 or 20 years and has not yet reached its limit. Future hydroelectric developments in this region would doubtless be a help to this industry, but it does not appear that they are a governing factor. Similarly, navigable rivers would be a benefit in some cases, but this is not essential for this industry. Of the mineral resources of this region it is probable that the coal situation has been more thoroughly investigated than any other, and information on this mineral is reasonably accurate. According to the State Geological Survey of Tennessee there are 25,000,000,000 tons of coal in the State, almost all of it being found in the Tennessee River Basin. In general, the quality is good and the beds, though not thick, are in the majority of cases workable. This coal outcrops at considerable elevation above the valley floors in the river basin immediately to the west of the Powell, Clinch, and Tennessee Rivers above Chattanooga and in the Sand Mountain range east of the Tennessee below that city. The Sequatchie River penetrates an important coal region for its entire length. Some coal seams outcrop on the hills within a few hundred feet of the Tennessee River just below Chattanooga. In general, however, the exposures are distant from the rivers mentioned from 5 to 15 miles. The bringing of navigation to the vicinity of the coal measures near Harriman has been seriously

discussed for some years, and less serious thought has been given to taking navigation up the Clinch and Powell Rivers. The improvement of the Sequatchie for navigation has never been given serious attention. It seems just to conclude that the probable movement of coal by water from these regions is not sufficient to justify the expense of providing adequate navigation on these rivers, but that if for any reason such navigation were provided a very considerable amount of coal would move by water, to the mutual advantage of the producer and the consumer.

171. The next most important mineral is iron ore. There is said to be 500,000,000 tons in the Tennessee River Basin, and it is not certain that all existing beds have been located. This ore is found generally in the same region as the coal, with some important deposits lying to the east of the Tennessee River and in the western part of the basin. As with the coal, it seems probable that with an improved river a considerable tonnage would be shipped out by water. Marble is found in large beds along the Tennessee and upper Clinch Rivers. It is now extensively quarried and shipped chiefly by rail. It seems to be well established that there are extensive beds on the Tennessee River which have never been worked and which will be opened up when adequate river navigation is provided. It is not thought that rail transportation will soon, if ever, be found to be adapted to these beds. The mica and feldspar deposits of the eastern part of this basin have put North Carolina among the leaders in the export of these minerals. The phosphate deposits of the lower central basin are important; the manganese and barite deposits of east Tennessee are large; clay (brick and fire) is abundant; high-grade clay suitable for pottery is found near the northern portion of the Tennessee-Mississippi divide and in western North Carolina; materials for cement manufacture are abundant; the zinc and copper ores are growing in importance; sand for building, molding, and glass is abundant and of increasing importance, but in the case of all these minerals, and others that might be mentioned, nothing has yet been found that justifies a prediction that their development will materially increase the volume of traffic on an improved river. There are those who are confident that such would be the case, and this office is not prepared to say that such opinions are wrong. The future of these minerals is not clearly enough seen to warrant an expression of opinion in the matter.

172. A consideration of foreign minerals in connection with cheap electric power in large quantities suggests a very marked growth in the electrochemical industry in this region. It appears that this industry, although one of the newest, is also one of the most rapidly growing industries throughout the world, and that the location of such plants depends almost entirely on the source of cheap electric power. Given this indispensable commodity, and the raw material, even though it be large in bulk and weight, can with profit be brought long distances to the source of power. For instance, the Aluminum Co. of America is bringing large quantities of bauxite from South America to East St. Louis, where the electric power from the Keokuk Dam is available. The Southern Ferro-Alloys Co., of Chattanooga, brings 75 per cent of its scrap steel (the chief raw material used) from north of the Ohio River, as do other ferro-alloys companies in this part of the country. The American Lava Co., of Chattanooga,

brings its raw material—talc—from China and India. In the case of the Chattanooga companies, the power from the Ocoee and Tennessee Rivers (in the Tennessee River system) is the governing factor. Perhaps the largest electrochemical industries in this country are located at Niagara Falls because of the cheap power available there in large quantities, and for these industries chromite is brought there from New Caledonia, Turkey, and Russia; tungsten from South America and Malaysia; and (before the war) potash from Germany.

173. If something like 2,000,000 horsepower in hydroelectric development can be installed in this region a market for this power can be found only in the electrochemical industry. If this power is cheap enough, there seems to be no doubt but that such industries will develop about as fast as the power is made available. If local minerals are found to be useful in these industries, this will unquestionably be an added inducement for such developments. On the other hand, the usefulness of local minerals is not essential, and, if necessary, foreign minerals will certainly be brought to the source of power. At present more foreign than local minerals are being used in these industries in this region, and should this continue to be the case, as is possible, this suggests tonnage for an improved river. Nothing definite can be said of this phase of the subject at this time further than that here lies open a most interesting and perhaps useful field for further research.

174. It will be noted that in the foregoing it is stated that electrochemical industries require cheap power. Unless it be cheap, large quantity is no inducement. In the Tennessee River Basin the quantity potentially available is undoubtedly large, but whether this can be developed cheaply enough is another matter. Recently the demand from the local electrochemical companies for power has been in excess of the supply, but so far as known to this office the power supply companies are now taking no steps to increase their output. To what extent this is due to high cost of materials and labor and an uncertain financial outlook, and to what extent it depends upon conditions inherent with the hydroelectric situation in this region it is impossible at this time to state. This condition does, however, indicate the advisability of further investigation and study before the Government commits itself to any specific line of action in matters so closely related to future industrial developments in this region as would be a comprehensive plan of river improvement throughout the Tennessee River Basin.

HYDROELECTRIC SITUATION.

175. It has long been known that this section of the South had valuable resources in its cotton and its various mineral deposits, including coal, but so far as the Tennessee Basin was concerned it seemed better to take these resources, including the coal, to distant factories than to bring the factories to the resources. Of recent years, however, there has been made a series of hydroelectric installations, both in this basin and immediately adjacent to it. Energy in the form of coal may be carried long distances with economy, but in the form of electricity it must be used within 200 or 300 miles, at the most, from its source of generation if undue losses are to be avoided. With electrical energy being generated in this region, and with such

energy increasing in quantity, numerous manufacturing plants have recently been established in this neighborhood and the indications are that much more growth in this direction is to be expected in the immediate future if the hydroelectric development continues. This suggests a new and perhaps important source of commerce on the navigable waters in the Tennessee Basin, which should not be overlooked in any studies made of the future to be expected on these streams.

176. In addition to developing commerce in this territory the actual or possible growth of the hydroelectric industry in this region has another very important bearing on future plans for this river system. The greater part of all electrical energy now generated in this basin comes from heads created by four dams, three on tributaries to the Tennessee and one (at Hales Bar) on the main stream. This latter dam includes suitable provisions in the form of locks amply to protect the interests of navigation. Another power-navigation dam is now under construction near Florence (the Wilson Dam), the plans for two other similar structures on the Tennessee proper have already received congressional approval, and a third is proposed in the Muscle Shoals section. Water falling in this basin has, then, two possible uses—one the generation of power and the other the carrying of freight. If future power studies underestimate the importance of water transportation, a valuable asset of this region may be impaired or lost. If navigation studies neglect the power possibilities of the many streams in this basin, the future industrial development of this region may be stunted or diverted to other regions less favored by nature in this particular way. As a rule, the Engineer Department has taken care that the interests of navigation were sufficiently protected and has left to other agencies most of the details of the question of the best use of the water in the development of power. An exception to this rule is found in the case of the existing and approved combined power and navigation dams on the Tennessee proper. Here were found special instances where it was manifestly to the best interest of both navigation and power development to build structures which would make suitable provision for both. At Hales Bar, for instance, satisfactory navigation could be procured only by the construction of a high dam which was admirably suited as well for the generation of power. Passing upstream from this point along the main river, it is evident that the best navigable conditions from Chattanooga to Knoxville would be secured if similar structures could be built adapted both to the needs of navigation and to the generation of power. While existing information indicates that here such a project would be very difficult and expensive, and hence less desirable, sufficient data definitely to eliminate such a project does not exist. On the tributaries it has never appeared that the construction of locks and dams for navigation has been justified by existing conditions, yet it is on these tributaries that are found some of the most promising sites for power dams, and it is within the limits of possibility that if large blocks of power were generated here industries would come to the same vicinity. This would materially alter the situation as affecting the desirability of improvements for navigation.

177. To give point to the somewhat hypothetical condition just referred to, the developments of the Aluminum Co. of America in this region may be cited. This company requires for its operations large

quantities of cheap power. Such power, ample in quantity and cheapness, was located in the hydroelectric possibilities of the upper reaches of the Little Tennessee River, well above any region where it could be expected that navigation would ever be advisable. Installations were planned capable of developing something like 350,000 horsepower, and of this one installation of about 70,000 horsepower has been completed and is now in operation. With this power available a manufacturing plant employing 2,700 men was built at a point about 17 miles south of Knoxville and there, 6 miles from the Tennessee River, a new town, Alcoa, came into existence. This office has no detailed information as to the future plans of this company, but judging solely from the comparison of existing with proposed power output this town, the plant, the number of employees, and the tonnage may eventually be five times the present size. For manufacturing purposes this company now brings by rail from St. Louis, Mo., from 9,000 to 10,000 tons of raw material annually and eventually this may be 50,000 tons of incoming raw material only. The Aluminum Co. is now using or planning to use water transportation for their raw material between New Orleans and St. Louis, and had there been all the year round reliable navigation on the Tennessee River it is conceivable that water transportation would have proved to be most advantageous between St. Louis and the Alcoa plant. All the year round navigation from the Ohio River to the vicinity of Alcoa does not now exist, it never has existed, and there is no approved project or study which gives hope that a definite date can be set when it will exist. And for this reason, presumably, this company is supposed never to have given even passing thought to water transportation in connection with this large undertaking. In the absence of information to the contrary, it seems possible that, if not properly guarded against by suitable studies in the near future, what has already developed in this case may reappear again and again to the mutual disadvantage of power interests, new industries, navigation interests, and the public at large.

178. The future tonnage of this river system depends in no small degree upon the future hydroelectric developments possible in this basin. The water power still undeveloped here is variously estimated from 800,000 to over 2,000,000 horsepower. More or less superficial studies of this situation have been made by the Government bureaus, private interests, and semipublic agencies and the chapter of this report on the hydroelectric possibilities of this region gives what is believed to be a fair summary of the best information (though still incomplete) now available on this subject. If the water powers of this region are to be fully developed, it is not sufficient to produce the power. When power is made available in large quantities the market for it must also be assured. The use of electricity may be roughly divided into two general classes, (a) that used for lighting, city and interurban traction, railroads, and to supplant individual steam units for driving the machinery of a wide variety of industrial plants, and (b) that used in the electrochemical industry in the electric furnace, etc. Under the most favorable conditions the change from steam to electricity on railroads and in industrial plants will be made slowly, and even when completed would not require more than 10 per cent of the electrical power supposed to be available in this region. On the other hand, in the electrochemical industry the conditions seem

to be very different. Here electricity must be used; it must be used in large quantities, and that continuously with little variation, day and night, for weeks and months without interruption. This, then, suggests a possible market for all the power that may be developed in this region; it is a new and growing industry, which seems to be peculiarly suited both to the power possibilities and to the mineral resources of this section.

179. The estimates of 800,000 to 2,000,000 horsepower available in undeveloped water powers in this region are based in large measure on studies of existing topographic maps of this area, supplemented in some instances by more or less complete investigations in the field. In such studies it is usually assumed that dam sites are satisfactory when the surface indications are favorable and that the costs due to the overflow of private property will not be prohibitive. As a matter of fact, it is not necessary to leave the valley of the Tennessee to find instances where dam sites supposedly satisfactory proved to be very poor as construction proceeded or where a most desirable site from surface inspection had to be abandoned upon closer investigation. In general, it is reasonable to hope that satisfactory dam sites in sufficient number and with proper locations may be found, but it is certain that to locate them and to test them properly will take more time and money than is often realized.

180. Flowage damages and flood reduction by reservoirs may well be mentioned at the same time. While not so troublesome along the Tennessee as they are along some other rivers, floods do occur and at certain times and places have given serious trouble. Their volume is large, and to control them by means of reservoirs would require enormous storage capacity. To develop water power to the extent of obtaining a million or two horsepower will also require a large amount of storage, enough, perhaps, to carry surplus water not only from a wet month to a dry month, or from a wet year to a dry year, but from a series of wet years to a series of dry years. Such storage runs into capacities that must be measured by the billions or the tens of billions of cubic feet, and such storage can be obtained only where broad lowlands can be permanently submerged for long distances. If all the storage needed for the maximum power development can be found there is hope that this will perceptibly diminish the height of maximum flood stages. Topographically the Tennessee basin seems to be unusually well adapted to such treatment in that on all the important tributaries may be found broad, long valleys having but a gentle slope. These occur not only on the lower reaches but often in the middle or upper sections, where they would be most helpful in securing large storage. It is also true that as compared with the basins of other large rivers in the United States there are fewer roads and railroads, cities, and towns situated low in these valleys. Yet it is also true that such improvements are found to some extent in most of these valleys and also that in every case the soil of these lowlands is the most fertile and is now in the highest state of cultivation. From all information at hand, it appears that here will be found the most serious obstacle to an extensive program of hydroelectric development, and that only by the most careful and thorough study can there be any hope of finding a solution of these difficulties satisfactory to all concerned.

181. Two power navigation dams were proposed by the Engineer Department for the Tennessee River, one at Crow Island below Chattanooga, and one near Caney Creek above that city; studies and plans were made for them, their construction was approved, and funds for that purpose appropriated by Congress. Attempts were then made to secure title or otherwise to protect the Government from flowage damage claims by condemnation proceedings, etc., with the result that it was soon found that the cost of this protection would so far exceed all estimates that the construction of these dams no longer came within the limits of proper economy. The construction of these dams was accordingly indefinitely postponed and the funds provided for that purpose have been diverted to other uses. A promising reservoir site with large storage on the Little Tennessee River was rejected by the Aluminum Co. after brief investigation because of the high claims for flowage damage that would be involved. On the other hand, in the case of the Hales Bar and the Wilson Dams private interests took this matter in large measure out of the hands of the Government officials and secured prices low enough to keep this element of cost within acceptable limits. Broadly speaking, the owners of farm lands are not much interested in power development and they are strongly attached to their farms. When, as in the case of Hales Bar and Wilson Dams, they are brought to a realization of the marked and lasting benefits which will follow in any particular case means can sometimes be found whereby flowage damages are kept within permissible limits. When they do not have this realization, experience indicates that the prices demanded and allowed in condemnation proceedings are very apt to become prohibitive. It would therefore seem that these claims can best be kept down when the particular industrial plant which will result from a given power development is known and it can be shown that the community will derive more benefit from this plant than it does from the farm and other lands in question. As indicated above, these large power installations will not, as a rule, be justified until their market is assured, and it would therefore seem that this market could be used as an argument to overcome opposition more often than would otherwise be possible.

182. Considering the relations which have existed in this region between the Government and private investors where hydroelectric developments are concerned, it may be stated that on the Ocoee and Little Tennessee Rivers large hydroelectric installations have been made under conditions which seem to be entirely satisfactory both to the Government and to the interests concerned. At Muscle Shoals some combination of private capital with Government activity was seriously considered for a time, but the final result has been that all work there is being done by the Government. At Hales Bar arrangements were made whereby part of the structure was built by the Government and part by private interests, and the power there generated is sold by the private interests. Present arrangements here seem to be satisfactory, but there is some doubt if the same agreement would be accepted at this time by private interests for another power dam on the Tennessee River. On the Clinch and French Broad Rivers hydroelectric developments have been proposed and either postponed or abandoned, and it is supposed that governmental restrictions contributed in some measure to this result. At the last session of Con-

gress a bill was passed with a view of clarifying the relations existing between the Government and private interests in hydroelectric development. This act has been in force for so short a time that its effect in this region is not yet apparent. If the proposed survey should result in definite and acceptable recommendations in specific cases where the interests of navigation and hydroelectric development appear to overlap, it would seem that this might be of benefit to all concerned.

IMPROVEMENT FOR NAVIGATION.

183. It is believed that the true object of river improvement is to provide a freight-carrying route over which will move commodities which in the absence of these improvements would either be not moved at all or would be hauled less advantageously by other carriers. Another object sometimes attained by the improvement of rivers has been the reduction of railroad freight rates as a result of making the river route an actual or potential competitor of the rail route. One of the most conspicuous features of the Tennessee River which have a bearing on the desirability of its future improvement is the fact that it is not closely paralleled by railroads. From Knoxville to Riverton the nearest parallel railroad is distant from the river from 5 to 20 miles, except for two or three short stretches, while for 200 miles below Riverton there is no parallel railroad within competing distance. Theoretically, then, the effect of the improvement of the Tennessee for through traffic from Knoxville to Paducah should be to stimulate the development of a large section of the valley which has heretofore been retarded due to inadequate transportation facilities, and this with a minimum of interference with the existing rail routes in the valley. In this connection the statements of an industrial agent of the Southern Railroad in Appendix D are of unusual interest.

184. Several million dollars have been spent improving the Tennessee River for navigation and as a result there now exists a minimum navigable depth of 4 feet at low water from Sheffield to the mouth. Above this city there exist a number of reaches having from 3 to 6 feet navigable depth at low water, which are partially or wholly disconnected from each other at low-water stages that may exist for several months each year. In addition, the construction of the Wilson Dam, now under way, is a complete though temporary bar to all navigation from the lower section of the river to the part above the dam. With the expenditure of so much money on the improvement of this river it would seem that there should have been an appreciable increase in the amount of tonnage moving over it. As a matter of fact, there has been no such increase, the tonnage has fluctuated from year to year and recently has shown a tendency to decrease rather than to increase. Some have deduced from this that further expenditures by the Government for river improvement on this system at this time are unwarranted, others, notably the river interests, are positive that these expenditures should continue but along somewhat different lines than those followed up to this time. The line of reasoning which leads to the conclusion that tonnage should increase with the amount expended on the improvement of the river is so well known that it is not believed to be necessary to repeat it here. The line of argument which leads to the conclusion that appropriations should continue

under such conditions as exist on this river is not new, but its application in this case is deemed to be worthy of more consideration at this time. To appreciate properly this point of view, a more detailed statement of the present condition, which has resulted from previous or existing projects, is needed and this is given below.

185. (a) Present plans for the improvement of the section from Knoxville to Chattanooga (188 miles) call for an extreme low-water depth of 3 feet, this to be obtained by open-channel methods, and for a concrete lock and dam at foot of Caney Creek Shoals to provide 6-foot navigation for 24.6 miles. Open-channel work is about 50 per cent completed, the work having been done in several reaches still being disconnected at low water. No work has been done on the lock and dam. The remainder of the open-channel work has been suspended for the time being, due to the fact that navigators show no disposition to extend the use of the existing 3-foot channels nor do they show any appreciable interest in the additional 3-foot depth in the unfinished portions of the project. A 6-foot low-water depth seems now to be the minimum that interests them.

(b) From Chattanooga to Hales Bar, 33 miles, there now exist an extreme low-water depth of 6 feet caused by the Hales Bar Dam.

(c) From Hales Bar to head of Hobbs Island, 125 miles, 5-foot navigation is now possible for about five months of the year. The minimum low-water depth is 0.8 foot. Of the project for 6-foot canalization adopted by Congress for first 40 miles below Hales Bar, work on first dam below Hales Bar has been begun and a second dam is authorized. For the remaining 85 miles the project calls for a 5-foot low-water depth to be obtained by open-channel methods. It has been recommended that canalization be substituted for open-channel methods in this section by the construction of three more locks and dams.

(d) From Hobbs Island to Florence Bridge, 80 miles, a 6-foot depth is to be obtained by canalization through the building of Locks and Dams Nos. 1, 2 (Wilson Dam), and 3 in the Muscle Shoals section. Work on the Wilson Dam only has been begun. In its present condition the river has a 5-foot navigation below Hobbs Island to the Elk River Canal for about six months of the year. Just above the canal navigation is nearly impracticable for four months of the year. From the Elk River Canal to the Muscle Shoals Canal there is a 5-foot navigation for six months and an interruption of about four months. The construction of the Wilson Dam has for the present completely blocked the river for traffic and no navigation is possible there.

(e) From Florence or Sheffield (below the Wilson Dam) to Riverton, 30 miles, there is 4.5 foot navigation the year round.

(f) From Riverton to the mouth (Paducah) there is 4-foot navigation the year round.

186. Experience on this river seems to prove that improving the navigable conditions on a series of pools practically disconnected at low water will not increase the tonnage on them at such stages; neither will it increase interpool navigation during the parts of the year when such navigation is physically possible. It is true that from Florence or Sheffield to the mouth of the Tennessee there now exists the minimum low-water depth which river interests felt would insure the proper use of this part of the stream, and yet the com-

merce on this section is little, if any, greater than it was before this depth was obtained. Since the difficulties of interpool navigation did not exist below this city, and yet the results are much the same, this situation was made the subject of special investigation which has revealed the conditions so often found along navigable rivers of inadequate terminals, alleged discrimination or interference from outside sources, inadequate financial resources, lax business methods, etc. Tens of thousands or even hundreds of thousands of tons of freight may be carried on a river in the course of a year by a small number of boats each operating independently of the others and all operating only when the tonnage is plentiful and the profits are good, and suspending service and leaving their patrons without any transportation service when the tonnage and profits are small. When, however, it comes to a tonnage running into the millions, which it is believed is now possible on the lower Tennessee, such methods are sure to fail and it is believed that here is found to no small extent the real cause of the lack of growth of river traffic over this section.

187. Wherever transportation companies have successfully carried their millions of tons per year, whether it be over railroads, on the ocean, the Great Lakes, or the Monongahela River, it is believed that it will be found that the affairs of these companies have been in the hands of especially able and energetic business men with ample financial resources behind them, who devoted their entire time and attention to these affairs. If there are any such men and resources now wholly devoted to the navigation of the Tennessee River, this office has been unable to locate them. This naturally raises the question: Why are not able men with ample resources interested to this extent in navigation on this river? If such a man should begin to investigate conditions with a view to deciding if there were here an opening for a profitable investment, as it is possible that some have, he would learn first that, in addition to the section below Sheffield, there are above these numerous other sections varying in length up to 80 miles where a boat drawing 3 feet can operate the year round. These sections are disconnected at low or medium stages and it is not possible to tell with certainty just which months between June and January will be low-water months. While much freight can be handled in these pools, that which interests him as a man of large affairs must be carried between pools or from the point of origin to the mouth of the river. Should he then inquire when this interpool navigation will be possible, or what amounts to the same thing, when will there be all the year round navigation for a 6-foot draft or better from Knoxville to the Ohio River, he would learn that although over 100 examinations and surveys have been made by the Engineer Department of the Tennessee River and its tributaries in the last 90 years, no such date can be set. One of these surveys extended from the source to the mouth of the Tennessee River proper and omitted the tributaries; of the remainder, each one covered only some part of the main stream or a part of one of the tributaries, and heretofore no attempt has been made to include in one study all the potentially navigable waters of the entire Tennessee River system. There is no approved project which would lead one to hope that on any specific date through navigation of the entire Tennessee River will become an accomplished fact, and in the absence of even a definite hope of attaining this

result no individual or interest dealing with large affairs will give the navigation of this river system serious consideration.

188. It is believed that comparatively small pools mean in the transportation business on the Tennessee River small men with small resources operating in a small way and obtaining small results. It is the hope and belief of local river interests that all-the-year-round navigation for the entire river system would mean large men, large resources, and large results, but unfortunately the experience which explains the disappointing conditions on small pools does not prove that success must follow with the opening of through all-the-year navigation. The results below Sheffield seem to point to the opposite conclusion. Here, however, it is true that neither Florence nor Sheffield is a large city, nor does either command large financial resources, and between Sheffield and the Ohio the population near the river is sparse and not wealthy. It does seem that there is in this region a good opportunity to build up a very respectable tonnage, and that this has not been done, probably, because the man with the ability, resources, and courage necessary to make such an enterprise a success has not yet appeared on the scene.

189. In the last analysis large tonnage will appear on a river only when the territory that it serves produces or consumes a large amount of freight, and when this freight can be moved by water cheaper than by any other method. As has been mentioned already, the territory served by the Tennessee River and its tributaries, except for a few cities, is comparatively undeveloped except for agriculture, since the railroads of the region, not being in general located near the rivers, have drawn population and manufacture away from them rather than toward them. If this basin had reached or was approaching its limit of industrial development this would indicate that little was to be hoped from future development of the river. Fortunately, this is not the case. This region is undoubtedly rich in its mineral and hydroelectric possibilities. The indications here are that the only present doubt is whether it is now or will be soon economical to push new developments of this kind. When it is found to be good economy to begin such developments it would seem that it should be possible so to direct this future growth as to make the use of an improved river to the marked advantage of all concerned, existing transportation lines included, and if this is done river tonnage in quantity must surely follow. It is proposed for this survey that it shall be so conducted as to clear away all the doubts that now enter into this problem, and from the studies made so far it seems that much can be done in this region toward putting navigation in its relation toward future industrial growth on a more substantial foundation than has ever before been possible here or perhaps elsewhere. It is hard to believe that money spent in this way could be wasted, and the economic benefits that are possible seem to be almost unlimited.

EXISTING INFORMATION.

190. The extent to which various agencies have investigated the different topics which it is proposed to include in this survey is of interest at this time, both as showing the basis of the opinions given relative to present conditions and future possibilities, and also as showing how much of the ground has already been covered and need

not be gone over again in any future survey. Considerable time and effort has been spent in investigating various sources of information and a great deal that is of interest has been obtained from public, semiprivate, and private sources, the quantity and accuracy varying widely in different cases. The results obtained are briefly summarized in the following paragraphs:

191. *Maps*.—Something over one-half of the upper part of the basin of the Tennessee has been covered by the United States Geological Survey in topographic sheets published on a scale of 2 miles to 1 inch with 100-foot contours. This scale is too small for anything approaching a detailed study of either navigation or hydroelectric problems. These maps are, however, very valuable as reconnaissance maps from which drainage areas can be roughly computed and on which the more promising reservoir sites are easily recognized. Some larger scale topographic sheets and geological sheets are available. These are valuable but not numerous enough to have any great effect on the scope of the proposed survey. The Engineer Department has made numerous surveys of the Tennessee River and its tributaries. In general, these are channel surveys and do not extend beyond the top of bank of the various streams, and, consequently, must be supplemented by additional surveys before they can be used in studies involving dams and reservoirs. The exceptions to this rule occur in the section from Hales Bar to the vicinity of Hobbs Island and in the Muscle Shoals and the Caney Creek sections. These give more topography, but having been prepared for a special purpose will have to be extended to be of use for all the purposes proposed for his survey. (See Chart IX.) Between Hales Bar and Chattanooga, on the Ocoee and on the Little Tennessee Rivers, good maps have been made by private interests which will be available to this office if needed in the course of the proposed survey. These maps, together with other work done in these regions by these interests, will materially reduce the amount of work to be done in the entire basin. Maps from other sources are neither numerous nor important. This subject is covered more in detail in Appendix A.

192. *Stream flow records and rainfall stations*.—Gauging stations have been maintained at various points in this basin over different lengths of time by the Engineer Department, the Weather Bureau, the United States Geological Survey, the Mississippi River Commission, and private interests and have recently been supplemented by additional stations needed in the course of this preliminary examination. The situation in this respect is best understood by a reference to Chart VII, and to the more detailed discussion covering stream flow and rainfall given in Appendix A.

193. *Hydroelectric conditions*.—The Wilson Dam now under construction by the Government at Muscle Shoals, the Hales Bar Dam on the Tennessee constructed by the combined effort of the Government and private interests, and the privately owned and constructed hydroelectric developments on the Ocoee and Little Tennessee Rivers have furnished much valuable information which has been freely used in the discussion of this subject in this report, and it is believed that this information has furnished an unusually sound basis for the opinions formed in this connection. It is also believed that should further studies or other activities along this line be authorized the

lessons learned by these ventures would all be available to this office and that they would furnish a valuable guide in matters of policy and standards for design and engineering procedure which should increase the efficiency and decrease the cost of any work that might be done. Appendix B gives a more detailed discussion of this subject. The appendix was written by a consulting engineer who has made it a point for a number of years to follow the trend of thought and activity in hydroelectric matters in this vicinity.

194. *Industrial and mineral resources.*—Information on these subjects has been sought from various bureaus of the Federal and State Governments, the chambers of commerce of the larger cities of this region, the Tennessee River Improvement Association, the industrial agents of the Carolina, Clinchfield & Ohio Railway and the Southern Railroad, and some of the leading manufacturers of the territory concerned. The field thus opened to investigation seems to be almost unlimited in extent, and all statements on these matters made in this report, including those in the various appendices, must be considered as being most general in their nature, since neither time, money, nor authority permitted detailed investigations along any one line. Generally speaking, the studies and future plans of every agency such as those mentioned above have been made in large measure independently of every other agency, and the fact that industrial development in this region has not progressed more rapidly in the past is due in no small degree to the fact that hydroelectric development, industrial development, and river navigation have been considered almost independently of each other when in fact they are very closely interrelated. The present preliminary examination has suggested the possibility that through this survey might be found the means of bringing all to a realization of their common interests, and it is believed that if the proposed survey is authorized considerable attention to this phase of the situation would be proper and to be desired.

TIMELINESS OF SURVEY.

195. A very brief reference to the influence which the topography of this region had on its settlement and industrial growth during the last century and a half will do much to make clear why such a survey as that proposed would be of value at this particular time. When the pioneers from the Colonies and States first began to move westward across the Appalachian Mountains there were no railroads and the early settlers sought the most easily traveled routes. These were found to lead through central New York and over the comparatively low and short passes of western Pennsylvania and Maryland into the region drained by the headwaters of the Ohio River. Railroads soon followed the same routes, the mineral resources of the northern Appalachian system were discovered and developed, the whole region became well populated, and industrial development progressed rapidly. With the recent growth of the hydroelectric industry came the realization that the basin of the upper Ohio was by nature well adapted to such a development, but at the same time it was evident that the valleys where reservoirs must be located were the sites of large and wealthy towns and cities, mines, enormous manufacturing plants, important railroads, etc., and that comprehensive hydroelectric development is now possible there only after hundreds of

millions or even billions of dollars have been spent in a thorough remodeling of the industrial growth of more than a century. The net result is that comprehensive hydroelectric development there is out of the question, and there will be an annual waste of millions of dollars worth of potential hydroelectric energy which must go on forever.

196. The passes through the Appalachian range into the basin of the Tennessee are higher, longer, and much more difficult than those to the north, and comparatively few settlers found their way through them into this valley. Railroads followed but slowly and offered relatively poor service. The mineral resources, though known, were little heeded and it came to be assumed that they did not compare in extent or value with those of the northern section. The Tennessee Valley, therefore, has become but sparsely settled, and industrial development here is still backward. With the recent growth of the hydroelectric industry has come the realization that the basin of the Tennessee River is by nature well adapted to such a development; that here the possibilities are perhaps even greater than those of the upper Ohio. While towns, cities, manufacturing plants, and railroads are now found located on potential reservoir sites, they are not nearly so large, wealthy, or numerous as those on the upper Ohio. There extensive hydroelectric development is out of the question; here it still lies within the limits of possibility. The mineral resources and other industrial possibilities of this region are not to be ignored, and of recent years industrial growth here has assumed respectable proportions. Left to itself, this continuing growth will inevitably flow to the valley bottoms, occupying the sites of reservoirs which are indispensable to proper hydroelectric development, and the history and waste of the upper Ohio may well be repeated on an even larger scale. If taken in time, and there is hope that it is not yet too late, it is probable that the future general industrial development will adjust itself to the special requirements of the hydroelectric industry without the growth of either being stunted or retarded and a duplication of the large economic waste of the upper Ohio may be avoided.

SUMMARY.

197. Briefly stated, it appears to be reasonably well established that in the basin of the Tennessee River there is about 2,000,000 horsepower in undeveloped hydroelectric energy. Much of this is capable of being developed economically. All of it has some effect, great or small, on existing or potential developments in the interest of navigation on this river system. These effects and the restrictions which might be imposed in the interest of navigation are surrounded by considerable uncertainty. It seems to be decidedly in the interest both of navigation and proper hydroelectric development that these uncertainties be removed by such a survey as that proposed.

198. The Government, as represented by the Engineer Department, is vitally interested from the outset in any plans for hydroelectric development in this region; first to see that these plans do not injure the actual or potential navigability of these streams, then to see that imaginary injury to navigation does not stop or curtail hydroelectric developments of real merit, and, finally, in some cases, to bring into

being combined navigation and power developments of a magnitude that could not be justified by either interest alone and unaided by the other.

199. This section is rich in undeveloped mineral resources. With a large quantity of cheap electric energy available these resources plus the minerals brought from a distance will make a large growth of industries of various kinds possible. Extensive industries indicate large shipments, and, if properly planned from the outset, much of this tonnage should move naturally over the rivers. To ascertain definitely to what extent this is probable, what further river improvement, if any, is thereby justified, and to what extent navigation and power interests can be combined in individual dams, are problems whose solution at this time has special merit. Questions of floods, drainage, etc., are of minor importance, but are inseparably connected with the more important problems above stated and should be included in such a study.

RECOMMENDATIONS.

200. It is therefore recommended—

(a) That a survey be made of the Tennessee River and its tributaries in the States of North Carolina, Tennessee, Alabama, and Kentucky, for the purpose of formulating a plan of future development of navigation on these streams in which just weight can be given in every locality to the effect which existing or proposed river improvements in that locality will have on any proposed project for the entire river system.

(b) That in making this survey there be included studies of all present or potential hydroelectric developments, the mineral and industrial resources of this basin, floods, drainage, and such other allied subjects as may have an appreciable influence on any project for river improvement that may finally be recommended, or as may reasonably appear to be necessary for protecting the interests of the Government when issuing permits for any proposed development by private parties that may in any way affect or have a bearing on future navigation of this river system.

(c) That these additional studies be as thorough as the law or the desires of Congress and available funds will permit.

HAROLD C. FISKE,
Major, Corps of Engineers.

[First indorsement.]

OFFICE OF THE DIVISION ENGINEER, CENTRAL DIVISION,
January 29, 1921.

To the CHIEF OF ENGINEERS, UNITED STATES ARMY:

1. Forwarded.

2. The Tennessee River is geologically old and is fortunate in having what may be termed "a fixed regimen." But little change takes place in its bed and banks from year to year and improvement works have usually been of exceptional permanency. Frequent surveys to determine changes are not so necessary here as where more rapid action is found. Many disconnected surveys have been made from time to time at various places along this stream where channel work was projected, but it was not until 1909 that a complete survey of the river was made from its origin, near Knoxville, to its mouth

near Paducah. This survey was made for the benefit of navigation and was comprehensive enough to include all that seemed to be necessary in the way of physical information on which to base a project for its improvement. The project adopted as the result of that survey has been the approved project from that time to the present with perhaps some minor changes. This work need not be duplicated, and no new survey for such purposes is now believed to be needed, although small detailed surveys for special purposes may be necessary from time to time.

3. The drainage area of this river is large, embracing 40,800 square miles, and its flow is nearly the same, in both high and low water discharge, as the Ohio River, but it is not subjected to nearly such high rises, so that danger from floods along this stream is of comparatively small importance. There are but two towns on the entire stream of over 10,000 population, i. e., Knoxville and Chattanooga, both on high ground where damage from floods is only occasional and never very serious. Extensive flood control by reservoirs or otherwise does not therefore seem to be demanded at this time and no surveys for this purpose are warranted at present.

4. The resources of the drainage basin of this stream, which are very considerable, must not be confused with the limited resources which are tributary to the river and which would be likely to furnish commerce for the stream. Information as to sources of possible traffic is not very difficult nor expensive to obtain.

5. From Knoxville to Chattanooga the valley of the river proper is from 10 to 30 miles in width, the production of which in bulk commodities suitable for water transportation has not yet proven important enough to warrant the investment of much money in river improvement. From Chattanooga to Muscle Shoals the river passes through a gorge cut through the ridge of mountains forming what is called the "mountain section," where the width of the valley is much narrower than above, industries few, and the slope of the river steep. Below Muscle Shoals the river again becomes much flatter in gradient, and from Riverton to the Ohio it partakes of many of the characteristics of streams flowing through an alluvial plain. In the uppermost sections, above Chattanooga, the report shows, the water slopes are not sufficient to warrant much promise for the commercial development of water power owing to the probable high cost of flowage damages and necessary low lifts for dams, although several possible sites near Knoxville are mentioned. In the middle or mountain section, between Chattanooga and Riverton, are found now two great installations for power, one completed at Hales Bar and one under construction at Florence, Ala. The examination of the district engineer shows that no other opportunities for further development of any considerable size seem very promising in this stretch, and also below Riverton his report shows that flat slopes and low banks make the development of power extremely unlikely in that stretch. The undeveloped power possibilities on the main stream are therefore shown to be few and require no extensive surveys.

6. Many of the tributaries above Chattanooga, however, particularly those on the south side, have power possibilities some of which have already been developed and many studies of others have been made heretofore by private interests. Substantially all the water

rights on the Hiwassee, French Broad, Little Tennessee, and Ocoee have already been acquired by allied water-power corporations. Many efforts have been made by the Government to induce a flow of water commerce on the most promising of these tributary streams, but they have all been abandoned now as a result of lack of commerce and all improvements on them instituted by the Government have ceased for the time being. How far the Government may go with propriety in making surveys to assist in the private development of water power, mines, etc., along these tributaries from funds appropriated for the improvement of streams in the interest of navigation, particularly where navigation is either impracticable or abandoned, is a question which is not touched upon in the district engineer's report. Heretofore, so far as known, a strict conception of the law has limited all such surveys to the primary purposes of navigation unless the acts of Congress have specifically required more. If the survey recommended by the district engineer is for navigation purposes alone, there is nothing in his report to show that all information that is necessary is not already contained in previous surveys. If it is to include surveys for water power and other industrial possibilities, some question arises as to the extent to which such a survey can go with propriety.

7. It should be noticed that the district engineer purposes making an extended survey of water power, mines, etc., to cost \$560,800, with the expressed purpose of saving private industry the necessity of going to much expense to make their preliminary estimates for water power and perhaps for other industries. In my judgment no survey can go to this length with propriety, but should be confined to the determination of such commercial possibilities as lie within the area tributary to the stream and which have some probability of contributing something substantial to the commerce of the river. It seems reasonable to assume that any such survey as is proposed at a cost much above the total amount appropriated for examinations for the entire country can not be legally undertaken without the explicit sanction of Congress.

8. Thus far \$14,220,921.49 have been expended on this stream, exclusive of the tributaries, mostly within the last generation. This has resulted in providing much better facilities for navigation. With this money many obstructions have been removed or obviated and the condition of the channels is much better than some years ago when the commerce was at its maximum. There is nothing in the within report to show that there is any valid demand for better facilities for navigation either now or in the near future, nor is it pointed out anywhere in the report that present facilities are insufficient.

9. The main purpose of the report is clearly an investigation into the water-power possibilities, mostly on the tributaries, with no explanation as to how it is expected that navigation will be benefited thereby. The extent, character, and cost of the proposed survey is so far beyond what seems reasonable that it should, in my opinion, not be commenced until further expression of the views of Congress can be obtained.

10. For the foregoing reasons I do not feel that I can consistently recommend the survey that is proposed by the district engineer.

WM. W. HARTS,
Colonel, Corps of Engineers, Division Engineer.

APPENDIX A.

REPORT OF ASSISTANT ENGINEER GERARD H. MATTHES.

CHATTANOOGA, TENN., *January 15, 1921.*

From: Gerard H. Matthes, Assistant Engineer.

To: Maj. Harold C. Fiske, District Engineer.

Subject: Certain features of proposed survey of Tennessee River.

In the following pages are set forth the main aspects of six subjects which have an important bearing on the work that may be required in the proposed Tennessee River survey. Taken in the order in which they are presented these subjects are: (a) Existing surveys, (b) stream flow and rainfall data, (c) floods and low-water flow, (d) preservation of regimen, (e) water power. (f) earthquakes.

EXISTING SURVEYS.

The drainage basin of the Tennessee is at the present time about 80 per cent surveyed by the topographic branch of the United States Geological Survey. Of the 66 topographic quadrangles which cover portions of the basin, 43 are on a scale of 1 : 125,000 (approximately 1 inch equal 2 miles), and 18 are on a scale of 1 : 62,500 (approximately 1 inch equal 1 mile). The latter, made of recent years, show contour lines drawn at intervals of 20 feet difference in elevation, and are of a high standard of accuracy, while the former, made mostly during the first 10 years of the existence of the Geological Survey (1882-1891), have 100-foot contours and are good only for reconnaissance purposes. In addition to these topographic quadrangles, the Geological Survey has covered about 55 per cent of the basin with its so-called geological folios, of which there are 28. These show in colors the location of the principal geological formations and furnish general information relative to the mineral resources. Most of these folios were made from 15 to 20 years ago. At this time 22 of the 28 folios are out of print and difficult to obtain.

The topographic surveys referred to are based on a triangulation system executed in part by the United States Coast and Geodetic Survey and in part by the United States Geological Survey, the main triangles of which are shown in Chart X. Of late years accurate traverse lines were run, and many of the recent surveys utilized this form of horizontal control where triangulation was lacking. In Chart X are shown all existing primary traverse lines run by the Geological Survey.

In order to establish elevations above sea level for these surveys extensive spirit-leveling operations have been carried on in the past. These consist of precise level lines, run by the Coast and Geodetic Survey and primary level lines run by the Geological Survey. The large number of permanent reference points or bench marks established in these operations are for the most part available at the present time; lists giving locations and elevations are obtainable in printed form. The approximate location of these level lines, or so-called vertical control, is shown in Chart XI.

The channel of the Tennessee River has been the subject of surveys for a period covering nearly a century, first by the Corps of Topographical Engineers, and later by the Engineer Department, United States Army, but in no instance did a single survey cover the entire river system. Chart IX shows the extent of river channels covered by these surveys, which aggregates 1,200 miles; it does not, however, show to what extent the later surveys have superseded the earlier ones. For the sake of simplicity the surveys have been classified in Chart IX into three distinct kinds, represented by as many symbols. The maps of the early surveys of 1832, 1876, and 1887 were mere outlines showing, usually on small scales, the location of banks, islands, and shoals, and rarely indicating depths of water or heights of banks. In some cases levels were run giving the fall from point to point, and from these river profiles were obtained. The surveys made in the nineties and in 1909 were more comprehensive and resulted in maps on scales ranging from 1 inch equal 250 feet to 500 feet; they show contours along the banks using the low water surface as a datum plane, and give information as to depths of water and character of river bottom. Reliable river profiles were obtained from these surveys, all of which were based on accurate traverse and level lines. Few of these surveys extend up the tributaries.

In 1912 resurveys were started by Capt. R. C. Moore under Maj. H. Burgess's direction, shown in Chart IX by means of the solid shading, in which the earlier survey data was utilized as far as practicable. The object of these resurveys was to obtain information, mainly of a topographic nature, extending some distance beyond the river banks; all elevations were referred to sea level. Contours were drawn at 5-foot and in some cases at 10-foot intervals. Systematic soundings and borings were made

in the river channel and furnish accurate information regarding low-water depths and the occurrence of bedrock. The extent of the topography taken is not sufficient, however, for the purpose of making complete studies of flowage lands for dams required for the improvement of navigation, and considerable additional surveying will be required in this direction. The value of these later surveys was greatly enhanced by the fact that they were carried up the tributaries for some distance. The latest and most complete surveys made by the Engineer Department on the Tennessee River are those of 1915 covering the Muscle Shoals section.

Through the courtesy of the Chattanooga & Tennessee River Power Co. the district engineer at Chattanooga has been furnished with a complete set of the maps prepared by that company of the area covered by the pool above the Hales Bar Dam, including a total of over 32 miles of river channel. These maps are on a scale of 1 inch equal 200 feet, and show the outlines of the original channel, as well as of the pool, but no contour lines.

In addition to the various surveys above mentioned, a number of profile surveys of tributaries have been executed by the United States Geological Survey and various State geological surveys, the object of which was to bring out the power possibilities on such streams. Considerable surveying and mapping has been done also by private companies in connection with water-power developments, notably on the Little Tennessee and Hiwassee Rivers and tributary streams. Some of this data has been furnished to the district engineer at Chattanooga, and the latter has received assurances of further cooperation in this direction.

The early surveys and maps here described were found of considerable value in the present preliminary examination. For the purposes of the proposed survey much of this material can be utilized in part or in whole. Thus, the triangulation system and the traverse and level lines will be of the greatest value and only need to be amplified in certain localities. The river-channel surveys can be utilized and no further channel surveys are required except where detailed information is needed at sites for proposed dams. The existing channel maps, however, except those of the Muscle Shoals to Hales Bar section, give practically no information beyond the river banks, and a large amount of additional topographic surveying will therefore be needed to make the intelligent planning of dams possible, especially as regards the extent of lands to be overflowed. In most cases this will require the complete surveying of all valley lands from hillside to hillside, and the extending of such surveys up all tributaries to corresponding elevations.

On the tributaries practically no mapping has been done by the Engineer Department, except where there seemed to be prospect of obtaining navigable channels, and it follows that no large-scale maps are at present available where such streams have considerable fall and could be utilized for power development. The only data shedding any light on the latter subject are a few river profiles above referred to and surveys made by corporations.

For the purposes of an investigation of navigation improvements, water-power possibilities, and flood reduction, such as here proposed, it will be desirable to prepare maps of all principal river valleys in the basin on a scale sufficiently large to show the following: Location of watercourses and, in the case of large streams that are navigable or capable of being made navigable, the configuration of banks, islands, and shoals; the location of all railroads, highways and roads, pole lines for power transmission, telephone and telegraph, bridges, locks and dams, buildings, and property lines marked by fences; the classification of flowage lands as (1) woodland, (2) pasture land, (3) cultivable land, (4) waste land by means of suitable symbols; the outlines of all wooded areas; the topography by means of 5-foot contours in the valley bottoms and of 10-foot contours along hillsides. The area surveyed should include the entire valley bottom, adjacent hillsides, and tributary valleys far enough to furnish complete information for making estimates of flowage lands and cubic capacity of reservoirs for the maximum height of dam that may reasonably be selected in any given locality. Where lands are known to be outside of any possible reservoir location, the topography need include only so much of the valley bottom and foot of hills as is subject to overflow by the greatest flood on record.

The present status of general maps of the Tennessee River region is so unsatisfactory that it is now impossible to find reliable information as to the number of square miles of area drained by the Tennessee River or any of its major affluents. The drainage area figures published in various Government and State reports differ by considerable amounts. Such figures as appear in this report must be regarded as approximate and subject to correction. The completion of the topographic mapping operations of the Geological Survey in this section of the United States would be of great value in the work to be undertaken by the proposed survey.

STREAM FLOW AND RAINFALL DATA.

The first systematic recording of river stages in the Tennessee River Basin began November 6, 1871, with the installation of the gauge on the Tennessee at Florence, Ala., by Maj. W. E. Merrill, Corps of Engineers, United States Army. The half century record obtained at that point is practically continuous and affords a reliable index as regards the extremes of high and low stages that may be expected.

In 1874-75, in connection with the investigation made by Maj. Walter McFarland, Corps of Engineers, for a "southern route to the seaboard," gauges were established on the Tennessee River at Knoxville, Kingston, Loudon, Chattanooga, Decatur, Johnsonville, and Paducah. Some of these gauges were not read regularly, however, until at a much later date. Regular readings were begun at Miltons Bluff (upper Muscle Shoals) on January 1, 1879. The first river stage observations on tributaries of the Tennessee were started in 1884 on Hiwassee River at Charleston, Tenn., on Clinch River near Clinton, Tenn., and on Holston River at Strawberry Plains, Tenn.

In common with river stage records kept elsewhere in the United States those in the Tennessee Basin, for the most part, have not been operated continuously by any one Federal Bureau. The Engineer Department, the Signal Service, the Weather Bureau, and the Geological Survey have established, discontinued, or taken over from each other, at various times, such gauges as their respective needs have demanded, and in a few instances gauges have been maintained by private concerns.

The first measurement of discharge of the Tennessee River was made March 30, 1888, at Florence, Ala., by Lieut. H. E. Waterman, of the Corps of Engineers. Comparatively little was done in this direction, however, by the Engineer Department until 1891, when measurements were made at Knoxville and Chattanooga, and later on at other points on the main river. The Mississippi River Commission made a number of discharge measurements near Birmingham, Ky., in 1903, and at Riverton, Ala., in 1911, 1917, and 1920. In 1920 under the direction of Hugh L. Cooper & Co., a number of measurements were made of the flow of the Tennessee at Florence, Ala.

The United States Geological Survey began stream gauging operations in the Tennessee basin in 1895 with the establishment of the gauging station at Asheville, N. C., on French Broad River. Since that time a total of 85 gauging stations have been established in the Tennessee Basin, mainly on the tributaries. It is unfortunate that many of these stations, after having been in operation but a short time, were abandoned because of lack of funds or because local conditions proved unfavorable for obtaining satisfactory results. Such records are of limited value, the period of time covered by them being inadequate for estimating, reliably, the entire range of high and low water conditions. In many instances the number and range of discharge measurements obtained is not sufficient to establish definitely the relation between stages and corresponding discharges.

In 1907 and 1908 the Geological Survey, in connection with an investigation for an Appalachian Forest Reservation, then being made by the Forest Service, operated as many as 43 gauging stations in the Tennessee Basin. In 1910 this number had been reduced to 12. On October 1, 1920, the number was 32.

By authority of the Chief of Engineers, a cooperative plan of stream-gauging operations in the Tennessee Basin was worked out between the office of the district engineer at Chattanooga and the water resources branch of the Geological Survey, whereby it became possible to proceed with the expanding of these operations in the fall of 1920, for use in this preliminary examination. By this agreement the Geological Survey office, formerly located at Nashville, Tenn., was transferred to Chattanooga and allotted space in the district office. Effort was made to start as much of this work as possible while the low-water season was on. Some of the stations so established utilize existing Weather Bureau gauges at which records have been obtained for some time past. It is hoped to utilize the early records at these points provided sufficient stability appears to exist between stage and discharge. In a number of cases gauges were reestablished that had been abandoned some years ago. By so doing a two-fold advantage was gained, i. e., much time and expense was eliminated in determining the relation between gauge height and discharge, and the old, and often useless, short record was made of new and practical value. The number of old records which it is expected to revive in this manner is 23. Because of the time and expense involved in rating new gauging stations, the establishment thereof was avoided wherever possible. Only 12 entirely new gauges have been installed since October 1, 1920.

TABLE 19.—*Clinch River gauge records.*

Stream.	Locality.	River-stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Clinch	Cleveland, Va.	Oct. 28, 1920, to date.	Engineer Department ¹	Oct. 28, 1920, to date.	Engineer Department ¹	Established for Tennessee River survey.
Do.	Clinchport, Va.	June 7, 1907, to Dec. 31, 1909.	Geological Survey ²	June 7, 1907, to Dec. 31, 1909.	Geological Survey	Do.
Do.	Speers Ferry, Va.	Feb. 4, 1865, to date.	Weather Bureau.	Oct. 29, 1920, to date.	Engineer Department ¹	Previous to July, 1897, records cover high-water season only. The record is continuous from July 1, 1897, to date.
Do.	Lone Mountain, Tenn.	Apr. 1, 1919, to date.	Geological Survey.	Apr. 1, 1919, to date.	Geological Survey	
Do.	Clinton, Tenn.	Dec. 1, 1884, to Apr. 30, 1889.	Signal Office.	Oct. 1, 1918, to date.	do.	
Do.	do.	Dec. 1, 1889, to Apr. 30, 1897.	Weather Bureau.			
Do.	do.	July 1, 1897, to date.	do.			Measurement made 1 mile above mouth. Published in 1896 Report of Chief of Engineers, pp. 2014-2020.
Do.	do.	July 1, 1920, to date.	Geological Survey.			
Do.	At mouth.	None.	Geological Survey.	Oct. 25, 1891.	Engineer Department.	
Do.						
Emory	Deermont, near Oakdale, Tenn.	July 15, 1920, to date.	Geological Survey.	July 15, 1920, to date.	Geological Survey.	Established for Tennessee River survey. Weather Bureau station, Tazewell, Tenn., and Geological Survey station, Arthur, Tenn., refer to same gauge.
Powell	Pennington, Va.	Oct. 27, 1920, to date.	Engineer Department ¹	Oct. 27, 1920, to date.	Engineer Department ¹	
Do.		Dec. 13, 1892, to Aug. 31, 1895.	Weather Bureau.	Mar. 15, 1920, to date.	Geological Survey.	
Do.	Arthur, Tenn., or Tazewell, Tenn.	Sept. 1, 1904, to date.	do.			

¹ In cooperation with United States Geological Survey for Tennessee River Survey.² In cooperation with Forest Service.

TABLE 20.—*Holston River gauge records.*

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Holston.....	Rogersville, Tenn.....	Mar. 10, 1902, to date.....	Weather Bureau.....	Jan. 1, 1904, to date.....	Geological Survey.....	Records cover high-water seasons only.
Do.....	Strawberry Plains, Tenn.....	Feb. 1, 1885, to Dec. 31, 1889.....	Signal Service.....	None.....	.....
Do.....	do.....	Jan. 1, 1890, to Mar. 31, 1897.....	Weather Bureau.....	do.....	.....
North Fork.....	Saltville, Va.....	June 11, 1907, to Nov. 12, 1908.....	Geological Survey ¹	June 11, 1907, to Nov. 12, 1908.....	Geological Survey.....	
Do.....	do.....	Nov. 2, 1920, to date.....	Engineer Department ²	Nov. 2, 1920, to date.....	Engineer Department ²	New gauge established for Tennessee River survey.
Do.....	Mendota, Va.....	Feb. 1, 1906, to date.....	Weather Bureau.....	Oct. 30, 1920, to date.....	Geological Survey.....	Reestablished for Tennessee River survey.
South Fork.....	Chilhowie, Va.....	June 10, 1907, to Dec. 31, 1909.....	Geological Survey.....	June 10, 1907, to Dec. 31, 1909.....	do.....	
Do.....	do.....	Nov. 1, 1920, to date.....	Engineer Department ²	Nov. 1, 1920, to date.....	Engineer Department ²	
Do.....	Bluff City, Tenn.....	July 17, 1900, to Dec. 31, 1904.....	Geological Survey.....	July 17, 1900, to date.....	Geological Survey.....	
Do.....	do.....	Mar. 10, 1902, to date.....	Weather Bureau.....	June 8, 1907, to Dec. 31, 1909.....	Geological Survey.....	Do.
Middle Fork.....	Chilhowie, Va.....	June 8, 1907, to Dec. 31, 1909.....	Geological Survey.....	Nov. 2, 1920, to date.....	Engineer Department ²	Occasional discharge measurements were made by Geological Survey, but no daily discharge record published. Reestablished for Tennessee River Survey. Referred to in Geological Survey Water-Supply Papers as "near Elizabethton."
Do.....	do.....	Nov. 2, 1920, to date.....	Engineer Department ²	Nov. 6, 1920, to date.....	do.....	
Watauga.....	Butler, Tenn.....	Aug. 14, 1900, to Dec. 28, 1901.....	Geological Survey.....	Nov. 6, 1920, to date.....	Geological Survey.....	
Do.....	do.....	Nov. 6, 1920, to date.....	Engineer Department ²	May 11, 1903, to Dec. 31, 1908.....	Geological Survey.....	
Do.....	Siam, Tenn.....	May 11, 1903, to Dec. 31, 1908.....	Geological Survey.....	None.....	Geological Survey.....	
Do.....	Elizabethton, Tenn.....	Dec. 1, 1909, to date.....	Weather Bureau.....	Aug. 8, 1900, to Nov. 23, 1901.....	Geological Survey.....	Several discharge measurements made by Geological Survey, but no daily discharge record published.
Roan.....	Butler, Tenn.....	Aug. 8, 1900, to Nov. 23, 1901.....	Geological Survey.....	None.....	Geological Survey.....	
Elk.....	Lineback, Tenn.....	Aug. 8, 1900, to Dec. 7, 1901.....	do.....	None.....	Geological Survey.....	
Doe.....	Blevins, Tenn.....	Dec. 16, 1911, to July 28, 1915.....	do.....	Dec. 16, 1911, to July 28, 1915.....	Geological Survey.....	Occasional discharge measurements were made, but no complete daily discharge record has been published. Reestablished for Tennessee River survey.
Do.....	Valley Forge, Tenn.....	Dec. 11, 1911, to Sept. 30, 1915.....	do.....	Dec. 11, 1911, to Sept. 30, 1915.....	do.....	
Do.....	do.....	Nov. 5, 1920, to date.....	Engineer Department ²	Nov. 5, 1920, to date.....	Engineer Department ²	
Do.....	Elizabethton, Tenn.....	June 15, 1907, to June 30, 1908.....	Geological Survey.....	June 15, 1907, to June 30, 1908.....	Geological Survey.....	

¹ In cooperation with Forest Service for Appalachian forest investigation, 1907-8.² In cooperation with United States Geological Survey for Tennessee River survey.

TABLE 21.—*French Broad River gauge records.*

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
French Broad.....	Wilson's Bridge, Shuford's Bridge, and Buck Shoals.	Aug. 1, 1877, to June 30, 1878.	Engineer Department.	Aug. 1, 1877, to June 30, 1878.	Engineer Department.	Low-water discharge, calculated during 1877-78 survey, is published in 1878 Report, Chief of Engineers, p. 531.
Do.....	Rosman, N. C.....	May 7, 1907, to June 30, 1909.	Geological Survey ¹	May 7, 1907, to June 30, 1909.	Geological Survey ¹	Established for Tennessee River survey.
Do.....	Penrose, N. C.....	Dec. 1, 1917, to date.....	Weather Bureau.	None.....	.....
Do.....	Blantyre, N. C.....	Jan. 1, 1921, to date.....	Engineer Department ²	Jan. 1, 1921, to date.....	Engineer Department ²	
Do.....	Horseshoe, N. C.....	Oct. 4, 1904, to Mar. 31, 1906.	Geological Survey.....	Oct. 4, 1904, to Mar. 31, 1906.	Geological Survey.....	
Do.....	Asheville, N. C.....	Sept. 17, 1895, to Dec. 31, 1901.	do.....	Sept. 17, 1895, to Dec. 31, 1901.	do.....	Original gauge at Bingham School Bridge. Maintained as regular gauging station until Dec. 31, 1901, and occasional discharge measurements made at this point until 1904. The Weather Bureau gauge is located at Smith Bridge. During 1904 several discharge measurements were made there, and beginning Jan. 1, 1905, this was adopted as a Geological Survey gauging station. All subsequent records are referred to the Weather Bureau gauge and record is complete.
Do.....	do.....	Mar. 19, 1903, to date.....	Weather Bureau.	Jan. 1, 1903, to date.....	do.....	
Do.....	Marshall, N. C.....	Dec. 1, 1917, to date.....	do.....	None.....	.....
Do.....	Newport, Tenn. (Old-town, Tenn.).	Sept. 4, 1900, to Nov. 9, 1901.	Geological Survey.....	Sept. 4, 1900, to Dec. 31, 1906.	Geological Survey.....	
Do.....	do.....	Oct. 27, 1902, to Dec. 31, 1905.	do.....	Aug. 16 to Dec. 31, 1907.	do.....	Bridge where gauge was established, washed away in 1902. New gauge installed on new bridge same year. Discontinued in 1905 and again used between the dates given in 1907 in connection with Appalachian forest investigation. Reestablishment for Tennessee River Survey Nov. 17, 1920.
Do.....	do.....	Aug. 16, 1907, to Dec. 31, 1907.	do.....	Nov. 17, 1920, to date.....	Engineer Department ²	
Do.....	do.....	Nov. 17, 1920, to date.....	Engineer Department ²	None.....	.....
Do.....	Leadvale, Tenn.....	Dec. 1, 1884, to Mar. 31, 1886.	Signal Service.....	None.....	.....
Do.....	Dandridge, Tenn.....	Dec. 1, 1904, to date.....	Weather Bureau.	Nov. 3, 1918, to date.....	Geological Survey.....	Shifting channel condition render discharge record unreliable.
Nolichucky.....	Embsville, Tenn.....	July 1, 1920, to date.....	Embree Iron Co.....	July 1, 1920, to date.....	do.....	Bridge and gauge washed out. Location is at Jones Bridge, 4 miles south of Greeneville. Not to be confused with Weather Bureau gauge. (See below.)
Do.....	Chucky Valley, Tenn.....	Sept. 6, 1900, to May 21, 1901.	Geological Survey.....	Sept. 6, 1900, to May 21, 1901.	do.....	
Do.....	Greeneville, Tenn.....	May 7, 1903, to Dec. 31, 1908.	do.....	May 7, 1903, to Dec. 31, 1908.	do.....	
Do.....	do.....	Apr. 7, 1919, to date.....	do.....	Apr. 7, 1919, to date.....	do.....	

Do.....	do.....	Jan. 1, 1916, to date...	Weather Bureau.....	None.....			Located just below Tennessee Eastern Power Co. dam, 5 miles below Birdsbridge and 10 miles southwest of Greeneville, Tenn. Suspendes gauge at Birdsbridge. Suspendes Jan. 1, 1916, by a gauge 5 miles downstream. On account of backwater influence from dam. Established for Tennessee River survey.
Do.....	Birdsbridge, Tenn.....	Nov. 1, 1906, to Dec. 31, 1915.	do.....	do.....			
Do.....	Morristown, Tenn.....	Nov. 15, 1920, to date...	Engineer Department ²	Nov. 15, 1920, to date...	Engineer Department ²		
North Toe.....	Spruce Pine, N. C.....	June 19, 1907, to July 1, 1908.	Geological Survey ¹ ...	June 19, 1907, to July 1, 1908.	Geological Survey.....		
Do.....	do.....	Apr. 21, 1920 to date...	do.....	Apr. 21, 1920 to date...	do.....		
Davidson.....	Davidson, N. C.....	May 19, 1904, to June 30, 1909.	do. ³	May 19, 1904, to June 30, 1909.	do.....		
Little River.....	Calhoun, N. C.....	May 4, 1907, to June 30, 1908.	do. ¹	May 4, 1907, to June 30, 1908.	do.....		
South Fork Mills.....	Sitton, N. C.....	May 18, 1904, to June 30, 1909.	do. ³	May 18, 1904, to June 30, 1909.	do.....		
North Fork Mills.....	do.....	do.....	do. ³	do.....	do.....		
Mud.....	Pinked, N. C.....	May 10, 1907, to Dec. 31, 1907.	do. ¹	May 10, 1907, to Dec. 31, 1907.	do.....		
Swannanoa.....	Naples, N. C.....	May 28, 1907, to June 30, 1909.	do. ¹	May 28, 1907, to June 30, 1909.	do.....		
Do.....	Swannanoa, N. C.....	do.....	do. ¹	do.....	do.....		
Do.....	Biltmore, N. C.....	do.....	do.....	do.....	do.....		(Established May 25, 1904, as benchmark station. A few discharge measurements were made, but daily stages were not recorded. Established for Tennessee River survey.)
Ivy.....	do.....	Jan. 1, 1921, to date...	Engineer Department ²	Jan. 1, 1921, to date...	Engineer Department ²		
Big Pigeon.....	do.....	May 25, 1907, to Dec. 31, 1907.	Geological Survey ¹ ...	May 25, 1907, to Dec. 31, 1907.	Geological Survey.....		
Do.....	Democrat, N. C.....	May 25, 1907, to June 30, 1909.	do. ¹	May 25, 1907, to June 30, 1909.	do.....		
Do.....	Canton, N. C.....	Jan. 1, 1921, to date...	Engineer Department ²	Jan. 1, 1921, to date...	Engineer Department ²		
Do.....	Clyde, N. C.....	do.....	do.....	do.....	do.....		
Do.....	Newport, Tenn.....	Sept. 4, 1900, to Oct. 12, 1901.	Geological Survey.....	Sept. 4, 1900, to Oct. 12, 1901.	Geological Survey.....		
Do.....	do.....	Dec. 14, 1902, to Dec. 31, 1905.	do.....	Dec. 14, 1902, to Dec. 31, 1905.	do.....		
Do.....	do.....	Dec. 1, 1906, to date...	Weather Bureau.....	Nov. 5, 1918, to date...	do.....		
Little Pigeon.....	Sevierville, Tenn.....	Nov. 22, 1920, to date...	Engineer Department ²	Nov. 22, 1920, to date...	Engineer Department ²		
East Fork Little Pigeon.....	do.....	do.....	do. ²	do.....	do. ²		

¹ In cooperation with Forest Service for Appalachian Forest Investigation, 1907-8.

² In cooperation with United States Geological Survey.

³ In cooperation with Biltmore Estate.

TABLE 22.—*Little Tennessee River gauge records.*

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Little Tennessee.	Franklin, N. C.	June 12, 1907, to July 12, 1910.	Geological Survey ¹	June 12, 1907, to July 12, 1910.	Geological Survey.....	Abandoned July 12, 1910, on account of effect of fish-trap dam; reestablished for Tennessee River survey.
Do.	do.	Jan. 1, 1921, to date...	Engineer Department ²	Jan. 1, 1921, to date...	Engineer Department ²	Records published by Geological Survey for period 1898 to 1915, inclusive, are unreliable on account of change in control discovered in 1918. Complete records have been obtained by the Knoxville Power Co. from Apr. 16, 1912, to date.
Do.	Judson, N. C.	June 25, 1896, to Sept. 30, 1913.	Geological Survey.....	June 25, 1896, to Sept. 30, 1913.	Geological Survey.....	Discontinued Dec. 1, 1917.
Do.	do.	Apr. 16, 1912, to date...	Knoxville Power Co.	Apr. 16, 1912, to date...	Knoxville Power Co.	Discontinued Dec. 1, 1917.
Do.	Almond, N. C.	Apr. 16, 1912, to Nov. 30, 1917.	do.	Apr. 16, 1912, to Nov. 30, 1917.	do.	Discontinued Dec. 31, 1918. Reestablished for Tennessee River survey.
Do.	Calderwood, Tenn.	Jan. 1, 1912, to Dec. 31, 1918.	do.	Jan. 1, 1912, to Dec. 31, 1918.	do.	Discontinued Dec. 31, 1918. Reestablished for Tennessee River survey.
Do.	do.	Jan. 1, 1921, to date...	Engineer Department ²	Jan. 1, 1921, to date...	Engineer Department ²	Abandoned Dec. 31, 1913, as Geological Survey gauging station; records complete up to that time, except that no discharge measurements had been made since 1911, nor had gauge been visited; reestablished Nov. 6, 1918, by Geological Survey.
Do.	McGhee, Tenn.	Sept. 1, 1904, to date...	Weather Bureau.....	Nov. 23, 1904, to Dec. 31, 1913; Nov. 6, 1918, to date.	do.	Stream flashy and high-water records uncertain.
Cullasagee.	Cullasagee, N. C.	June 13, 1907, to Dec. 31, 1909.	Geological Survey ¹	June 13, 1907, to Dec. 31, 1909.	do.	Records good; reestablished for Tennessee River survey Jan. 1, 1921.
Tuckasagee.	East Laport, N. C.	May 27, 1907, to Dec. 31, 1909.	do.	May 27, 1907, to Dec. 31, 1909.	do.	Knoxville Power Co. has checked the Geological Survey records from Nov. 1, 1897, to Jan. 1, 1912, and furnished complete stage and discharge records from Jan. 1, 1912, to date.
Do.	do.	Jan. 1, 1921, to date...	Engineer Department ²	Jan. 1, 1921, to date...	Engineer Department ²	Records fair; new station established for Tennessee River survey.
Do.	Bryson, N. C.	Nov. 7, 1897, to Sept. 30, 1915.	Geological Survey.....	Nov. 7, 1897, to Sept. 30, 1915.	Geological Survey.....	Records good.
Do.	do.	Jan. 1, 1912, to date...	Knoxville Power Co.	Jan. 1, 1912, to date...	Knoxville Power Co.	Records good.
Oconalufy.	Cherokee, N. C.	Aug. 27, 1907, to June 30, 1908.	Geological Survey ¹	Aug. 27, 1907, to June 30, 1908.	Geological Survey.....	Rough and rocky bed makes soundings difficult.
Do.	do.	Jan. 1, 1921, to date...	Engineer Department ²	Jan. 1, 1921, to date...	Engineer Department ²	
Scotts.	Dillsboro, N. C.	Aug. 26, 1907, to June 30, 1908.	Geological Survey ¹	Aug. 26, 1907, to June 30, 1908.	Geological Survey.....	
Nantahala.	Nantahala, N. C.	May 22, 1907, to Dec. 31, 1909.	do.	May 22, 1907, to Dec. 31, 1909.	do.	

Do.....	Wesser, N. C.....	April 15, 1920, to March 31, 1921.	.....do.....	April 15, 1920, to March 31, 1921.	.....do.....	Superseded by Almond station.
Do.....	Almond, N. C.....	Apr. 16, 1912, to Nov. 30, 1917.	Knoxville Power Co..	Apr. 16, 1912, to Nov. 30, 1917.	Knoxville Power Co..	Knoxville Power Co. has a complete stage and discharge record from Apr. 16, 1912, to Nov. 30, 1917.
Do.....	.....do.....	Feb. 3, 1921 to date.	Engineer Department. ²	Feb. 3, 1921, to date....	Engineer Department. ²	Reestablished for Tennessee River survey.
Cheeah.....	Millsaps, N. C.....	Aug. 24, 1907, to June 30, 1908.	Engineer Department. ²	Aug. 24, 1907, to June 30, 1908.	Geological Survey.....	Records made 500 feet above confluence with Snowbird Creek, but no permanent gauge was established. Measurements have been made of Snowbird Creek.
Do.....	Johnson, N. C.....	Nov. 1, 1912, to Dec. 31, 1918.	Knoxville Power Co.,	Nov. 1, 1912, to Dec. 31, 1918.	Knoxville Power Co.	Knoxville Power Co. has complete records of stage and discharge, Nov. 1, 1912, to Dec. 31, 1918; reestablished for Tennessee River survey.
Do.....	.....do.....	Jan. 1, 1921, to date.	Engineer Department. ²	Jan. 1, 1921, to date....	Engineer Department. ²	Gauge established June 24, 1911. Knoxville Power Co. has practically complete records of stage and discharge from July 1, 1911, to Dec. 31, 1918. No records were taken in 1916, 1917, or 1918, and those in 1919 and 1920 to date are incomplete because of uncertainty of rating curve.
Do.....	At its mouth.....	July 1, 1911, to Dec. 31, 1915; Jan. 1, 1919, to date.	Knoxville Power Co..	July 1, 1911, to Dec. 31, 1915.	Knoxville Power Co..	Tellico discharge measurements of Tellico River are recorded in Water Supply Paper No. 243, May 30 and Aug. 13, 1907. No permanent gauge was established.
Tellico.....						

¹ In cooperation with Forest Service for Appalachian Forest investigation, 1907-8.

² In cooperation with United States Geological Survey, for Tennessee River survey.

TABLE 23.—*Hiwassee River gauge records.*

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Hiwassee.....	Charleston, Tenn.....	Dec. 1, 1884, to Apr. 30, 1903.	Engineer Department.	May 6, 1899, to Dec. 31, 1902.	Geological Survey.....	{Previous to July 1, 1908, gauge record covered the high-water season only (Nov. 1 to Apr. 30); stage record is continuous since that date. During high water on the Tennessee River, backwater extends past this point, rendering it useless for discharge determination at such times. Reestablished as gauging station for Tennessee River survey.
Do.....	do.....	July 1, 1903, to date.....	Weather Bureau.....	Dec. 20, 1920, to date.....	Engineer Department.	
Do.....	Hayesville, N. C.....	May 20, 1907, to Dec. 31, 1909.	Geological Survey.....	May 20, 1907, to Dec. 31, 1909.	Geological Survey.....	
Do.....	Murphy, N. C.....	June 26, 1896, to Aug. 8, 1897.	do.....	Oct. 20, 1897, to date.....	do.....	{Uncertainty exists concerning correctness gauge heights previous to Oct. 20, 1897. No discharge records previous to that date.
Do.....	do.....	Oct. 19, 1897, to date.....	do.....			
Do.....	Reliance, Tenn.....	Aug. 17, 1900, to Dec. 31, 1913.	do.....	Aug. 17, 1900, to Mar. 26, 1913.	Geological Survey.....	
Do.....	do.....	Nov. 6, 1918, to date.....	do.....	Nov. 6, 1918, to date.....	do.....	{Discharge estimates Mar. 27 to Dec. 31, 1913, not made, on account of change in rating indicated by measurement of May 15 of that year. It was assumed that change took place Mar. 26 and no new rating developed.
Tusquitee.....	Hayesville, N. C.....	May 20, 1907, to Dec. 31, 1909.	do.....	May 20, 1907, to Dec. 31, 1909.	do.....	
Valley.....	Tomotla, N. C.....	June 29, 1904, to Dec. 31, 1909.	do.....	June 29, 1904, to Dec. 31, 1909.	do.....	
Do.....	do.....	Jan. 21, 1914, to Apr. 30, 1917.	do.....	Jan. 21, 1914, to Apr. 30, 1917.	do.....	{Low-water flow slightly affected by mills above.
Do.....	do.....	Oct. 29, 1918, to date.	do.....	Oct. 29, 1918, to date.	do.....	
Nottely.....	Ranger, N. C.....	Feb. 16, 1901, to Dec. 31, 1905.	Geological Survey.....	Feb. 16, 1901, to Dec. 31, 1905.	Geological Survey.....	
Do.....	do.....	Jan. 21, 1914, to Apr. 30, 1917.	do.....	Jan. 22, 1914, to Apr. 30, 1917.	do.....	{High-water discharge records are poor.
Do.....	do.....	Oct. 20, 1918, to date.	do.....	Oct. 20, 1918, to date.	do.....	
Ocoee.....	Copperhill, Tenn., or McCays, Tenn.....	Mar. 21, 1903, to Dec. 31, 1913.	Geological Survey.....	Mar. 21, 1903, to Dec. 31, 1913.	Geological Survey.....	
Do.....	do.....	Jan. 1, 1917, to date.....	do.....	none.....	do.....	{Published discharge records should be revised prior to 1913 in accordance within rating curve developed during that year. This affects high-water records only. Gauge readings now being obtained, but no discharge estimates made since 1913.

Do.	McHarg, Tenn.	May 1, 1917, to date.	Tennessee Power Co.	May 1, 1917, to date.	Geological Survey ¹	Records not published in Water-Supply Papers since Sept. 30, 1916. Private records available from Tennessee Power Co. to Dec. 31, 1919.
Do.	Emf, Tenn.	Jan. 1, 1913, to date.	do.	Jan. 1, 1911, to Sept. 30, 1916.	do.	
Do.	Parisville, Tenn.	Jan. 1, 1911, to date.	do.	do.	do.	
Do.	do.	do.	do.	do.	Tennessee Power Co.	
Toccoa.	Dial, Ga.	May 17, 1907, to June 30, 1908.	Geological Survey.	May 17, 1907, to Jan. 30, 1908.	Geological Survey ¹	
Do.	do.	Jan. 1, 1913, to date.	Tennessee Power Co.	Jan. 1, 1913, to date.	do.	
Do.	Blue Ridge, Ga., or Morgantown, Ga.	Nov. 25, 1898, to Mar. 31, 1903.	Geological Survey.	Nov. 25, 1898, to Mar. 31, 1903.	do.	
Do.	do.	Apr. 1, 1913, to date.	Tennessee Power Co.	Apr. 1, 1913, to date.	do.	Original gauge (1907-8) was at Butts Bridge, 2 miles above Dial.

¹ In cooperation with Forest Service for Appalachian Forest Investigation.

² In cooperation with Tennessee Power Co.

TABLE 24.—Tennessee River—Upper section gauge records.

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Tennessee.	Knoxville, Tenn.	Jan. 1, 1875, to Oct. 1876.	Engineer Department.	May 28 to Oct. 17, 1891.	Engineer Department.	Original gauge at old Gay Street Bridge was used until March 8, 1898. During reconstruction of this bridge a temporary gauge was put in at the Maryville R. R. (Southern Ry) bridge, and this was read Jan. 17 to Nov. 1, 1899. At that time readings began at another gauge 4,000 feet farther downstream and were continued at this point until Dec. 31, 1908. Jan. 1, 1909, readings began at present gauge which is located on the new Gay Street Bridge. Comparative readings made for determining relation between various gauges are published in Water-Supply Paper No. 263, p. 128. Gauge heights previous to Jan. 17, 1899, cover high-water season only. Since Jan. 17, 1899, readings are continuous. Because of character of gauge record and dredging done in river channel by Engineer Department the discharge record is not reliable. 1891 measurements by Engineer Department published in 1896 Report of Chief of Engineers, pp. 2014-2020.
Do.	do.	Feb. 1, 1883, to Dec. 31, 1889.	Signal Service.	Jan. 17, 1899, to Dec. 31, 1909.	Geological Survey.	
Do.	do.	Jan. 1, 1890, to date.	Weather Bureau.	Oct. 1, 1918, to date.	do.	

TABLE 24.—*Tennessee River—Upper section gauge records—Continued.*

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Tennessee.....	Loudon, Tenn.....	Oct. 21, 1874, to Oct. 1876.	Engineer Department.	Aug. 1, to Oct. 23, 1891.	Engineer Department.	<p>Engineer Department records are continuous from Oct. 21, 1874, to Oct. 1876. From 1876 to 1884 there is no record. From 1884-1896, inclusive, only high-water season records were kept. Since July 1, 1904, records are continuous. Measurements by Engineer Department in 1891 made at Huff's Ferry are published in 1896 Report of Chief of Engineers, pp. 2014-2020, and 1902 Report, p. 1763. There is no daily discharge record.</p> <p>Station is at mouth of Clinch River. Records of Engineer Department, Signal Service, and Weather Bureau prior to July 1, 1897, are intermittent, being chiefly high-water records; low-water records were obtained during 1891, 1895, and 1899. The Signal Service in "River stage records, 1858-1889," states that the zero of the United States Engineer gauge is 0.75 lower than that of the gauge installed in 1886 and that correction by that amount has been applied prior to Dec. 12, 1889, when readings began on the later gauge. Records are intermittent and cover only high-water periods. Discontinued Mar. 31, 1897. The Signal Service publication "River stage records, 1858-1889" states that a boat must be used to get readings above 24-foot stage. (1891 and 1892 measurements by Engineer Department published in 1896 Report Chief of Engineers, pp. 2014-2020. Four rating tables are published in Water-Supply Paper 353, pp. 98-100, applicable to river stage record from Apr. 1, 1874, to Oct. 21, 1913. Since that time record</p>
Do.....	do.....	Dec. 1, 1884, to Dec. 31, 1889.	Signal Service.....	.....	.....
Do.....	do.....	Jan. 1, 1890, to Dec. 31, 1895; July 1, 1904, to date.	Weather Bureau.....	.....	.....
Do.....	Kingston, Tenn.....	Dec. 1, 1874, to September 1876.	Engineer Department.	.....	.....
Do.....	do.....	Dec. 1, 1884, to Dec. 31, 1889.	Signal Service.....	.....	.....
Do.....	do.....	Jan. 1, 1889, to 1897.	Weather Bureau.....	.....	.....
Do.....	do.....	July 1, 1897.....	do.....	.....	.....
Do.....	Rockwood, Tenn.....	Dec. 1, 1884, to Dec. 31, 1889.	Signal Service.....	.....	.....
Do.....	do.....	Jan. 1, 1890, to Mar. 31, 1897.	Weather Bureau.....	.....	.....
Do.....	Chattanooga, Tenn.....	Apr. 1, 1874, to June 30, 1891.	Engineer Department.	1891 and 1892.....	Engineer Department.	
Do.....	do.....	July 1, 1891, to Oct. 21, 1913.	Weather Bureau.....	1897 to Oct. 21, 1913.....	Geological Survey.....	

is affected by back water from Hales Bar Dam and rating tables are not applicable; discharge is computed by slope formula, using a gauge at Cincinnati Southern R. R. bridge 7 miles above Chattanooga, for determining slope. Reestablished for Tennessee River Survey.

¹ In cooperation with United States Geological Survey for Tennessee River survey.

TABLE 25.—*Tennessee River—Middle section gauge records.*

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Tennessee.....	Tumbling Shoals.....	May 10, 1891, to July 20, 1892; Dec. 1 to 31, 1892.	Engineer Department.	.....	.....	Two discharge measurements were made Nov. 5 and 6, 1891, by Engineer Department. Published in 1896 Report Chief of Engineers, page 2019.
Do.....	The Suck.....	Jan. 1 to June 10, 1875; Sept. 1, 1872, to Dec. 31, 1874; May 10, 1891, to Nov. 30, 1892; Mar. 5 to May 12, 1893.	do.....	.....	.....	Record made, from May 12, 1893, from gage located below The Suck; previous records from gage at head of The Suck.
Do.....	The Skillet.....	May 10, 1891, to Nov. 30, 1892; Jan. 1, 1900, to May 4, 1901.	do.....	.....	.....	.....
Do.....	Hales Bar, Tenn.....	Jan. 1, 1907, to date.....	Weather Bureau.....	Jan. 1, 1914, to date.....	Chattanooga & Tennessee River Power Co. and Tennessee Power Co.	Chattanooga & Tennessee River Power Co. and Tennessee Power Co. have prepared complete discharge records since 1914. No discharge records have been published.
Do.....	Shellmound.....	May 10, 1891, to Mar. 16, 1892; 1892, to Sept. 6, 1892; July 8, 1893, to Oct. 21, 1893; Jan. 20, 1895, to Aug. 13, 1896.	Engineer Department.	.....	.....	.....
Do.....	Bridgeport, Ala.....	May 23, 1892, to Sept. 6, 1892; July 8, 1893, to Oct. 21, 1893; Jan. 20, 1895, to Aug. 13, 1896.	do.....	.....	.....	.....
Do.....	.....do.....	Aug. 13, 1896, to date.....	Weather Bureau.....	.....	.....	.....
Do.....	Guntersville, Ala.....	Aug. 13, 1896, to Dec. 31, 1896.	Engineer Department.	.....	.....	.....
Do.....	.....do.....	Dec. 1, 1904, to date.....	Weather Bureau.....	.....	.....	.....

TABLE 25.—Tennessee River—Middle section gauge records—Continued.

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Tennessee.....	Decatur, Ala.....	Sept. 30, 1875, to Apr. 30, 1883.....	Signal Service.....	Referred to in Weather Bureau publication as Upper Muscle Shoals.
Do.....	.....do.....	Feb. 5, 1884, to Aug. 31, 1893; May 10, 1895, to Apr. 9, 1909.....	Engineer Department.....	.....	.....
Do.....	.....do.....	Apr. 9, 1909, to date.....	Weather Bureau.....	.....	.....
Do.....	Miltons Bluff, Ala. or Upper Muscle Shoals.	Jan. 1, 1879, to Dec. 25, 1884; Aug. 27, 1890, to date.....	Engineer Department.....	.....	.....
Do.....	Gilechrist Chute.....	July 15, 1901, to Jan. 13, 1902.....	.....do.....	.....	.....
Do.....	Lock B.....	Aug. 27, 1890, to date.....do.....	Referred to in Weather Bureau publication as Lower Muscle Shoals.
Do.....	Lock 1.....	Aug. 24, 1890, to date.....	.....do.....	.....	.....
Do.....	Lock 9 or Lower Muscle Shoals.	Aug. 26, 1890, to date.....	.....do.....	.....	.....
Do.....	Florence, Ala.....	Nov. 7, 1871, to Feb. 10, 1901.....	.....do.....	1888-1913..... 1913 to date.....	Engineer Department. Geological Survey.....
Do.....	.....	Feb. 11, 1901, to date.....	Mississippi River Commission.	Fall of 1920.....	Hugh L. Cooper & Co.
Do.....	Head of Colbert Shoals Canal.	May 18, 1891, to Dec. 31, 1909.....	Engineer Department.....	Two discharge measurements, one at very low stage published 1896 report Chief of Engineers, pages 204-2020.

Do.....	Riverton, Ala.....	May 18, 1891, to Sept. 1, 1896.	.....do.....	1894-1899.....	Engineer Department.	1894 measurements published in 1896 report Chief of Engineers, pages 2014-2020. Mississippi River Commission made 6 high-water measurements in April, 1911, not published; 9 measurements in March, 1917, published in 1918 report Chief of Engineers, page 3500; and 7 measurements in April, 1920, not published. A table of corrections published by Weather Bureau in Daily River Stages, 1909-10, page 376, directs that 8.1 feet be added to all gauge readings obtained prior to Nov. 1, 1904, and 6.5 feet to all gauge readings between Nov. 1, 1904, and Dec. 31, 1907.
Do.....	.....do.....	Sept. 1, 1896 to date.....	Weather Bureau.....			
Sequatchie.....	Whitwell, Tenn.....	Dec. 8, 1920, to date.....	Engineer Department ¹	Dec. 8, 1920, to date.....	.....do ¹	Established for Tennessee River survey.
Elk.....	Elkmont, Ala.....	June 24, 1904, to Feb. 3, 1908; Jan. 20, 1919, to date.	Geological Survey.....	June 24, 1904, to Feb. 3, 1908; Jan. 20, 1919, to date.	Geological Survey.....	Reestablished Jan. 20, 1919, as regular Geological Survey station.
Big Bear.....	Red Bay, Ala.....	Aug. 24, 1913, to July 1, 1920.	.....do.....	Aug. 24, 1913, to July 1, 1920.	.....do.....	Discontinued July 1, 1920.

¹ In cooperation with U. S. Geological Survey.

TABLE 26.—*Tennessee River, lower section gauge records.*

Stream.	Locality.	River stage record.	Obtained by—	Discharge record.	Obtained by—	Remarks.
Tennessee.....	Johnsonville, Tenn.....	Oct. 1, 1875, to Mar. 10, 1877; July 1 to Aug. 18, 1877; Mar. 1, 1879, to Oct. 31, 1880; Jan. 1, 1882, to Apr. 23, 1883; Feb. 6 to Nov. 30, 1884; Jan. 1, 1885, to Dec. 31, 1889, to date.....	Signal Service.....	1910 to date.....	Geological Survey.....	(Record prior to 1890 too fragmentary to be of much value. Discharge measurements have been made at this locality by Geological Survey since 1910. The measurements made at Birmingham, Ky., by the Mississippi River Commission have been referred to Johnsonville gauge and used in computing rating table. (For history of this gauge up to 1913, see Water Supply Paper 353, pp. 195-240.)
Do.....	do.....	None.....	Weather Bureau.....	Sept. 6-19, 1903.....	Mississippi River Commission.	Discharge measurements were made at Birmingham, Ky., 67 miles below Johnsonville, from Sept. 6 to 19, 1903, by the Mississippi River Commission and are published in Water Supply Paper 353, page 201.
Do.....	Paducah, Ky.....	June 1, 1874, to Dec. 31, 1880, to date.....	Engineer Department.....			Gauge is at confluence of Ohio and Tennessee Rivers and is mentioned here as of general interest only. Two discharge measurements at Livingston Point made Oct. 19, 1894, and Nov. 6, 1895, are published in 1896 Report of Chief of Engineers, pages 2014-2020, and 1902 Report, page 1764.
Do.....	do.....	Jan. 1, 1890, to date.....	Weather Bureau.....			
Duck.....	Columbia, Tenn.....	Established Nov. 1, 1880, 1887, to Dec. 31, 1889, to Nov. 20, 1895; Oct. 21, 1904, to Dec. 31, 1908; Apr. 28, 1920, to date.....	Signal Service.....	Oct. 21, 1904, to Dec. 31, 1908.....	Geological Survey.....	
Do.....	do.....	Jan. 1, 1890, to Nov. 20, 1895; Oct. 21, 1904, to Dec. 31, 1908; Apr. 28, 1920, to date.....	Weather Bureau.....	Apr. 28, 1920, to date.....	do.....	Record is intermittent. April 28, 1920, the Geological Survey made this a regular gauging station.
Do.....	do.....	Jan. 1, 1890, to Nov. 20, 1895; Oct. 21, 1904, to Dec. 31, 1908; Apr. 28, 1920, to date.....	Geological Survey.....			
Do.....	Centerville, Tenn. ¹	Mar. 6, 1919, to date.....	do.....	Mar. 6, 1919, to date.....	Geological Survey.....	
Buffalo.....	Flatwoods, Tenn. ¹	May 29, 1920, to date.....	do.....	May 29, 1920, to date.....	do.....	

¹ Since Nov. 1, 1920, maintained for Tennessee River survey.

In Tables 19 to 26 all of the gauges that have been maintained at one time or another in the basin of the Tennessee are shown, together with the periods for which records are available. In a number of cases no measurements of flow were made and the discharge at the site of the gauge is not known. For this reason it was found necessary to list in separate columns the periods covered respectively by river stage observations and by records of stream flow. In Chart VII is shown the geographic distribution of the gauges. It will be seen from the foregoing that the Tennessee River region is well supplied with river stage and stream flow data, and this is the more fortunate since records of this kind are indispensable as a basis for studying the numerous problems relating to river improvement, flood control, and water power development that will form part of any such investigation as may be undertaken.

The total number of gauges in operation in the Tennessee Basin at the time of submitting this report is 58, and it is believed that these, together with a few more stations yet to be established, will provide sufficient stream-flow data for the purposes of the studies to be made by this office, except on such streams as may later develop possibilities for hydroelectric installations which are at present wholly unsuspected.

Attention is here called to the necessity of making provision, at an early date, for new gauges on the main river to take the place of old gauges whose usefulness is now ended or being threatened by the construction of navigation dams. The Florence gauge is located a short distance below the Wilson Dam, now under construction at Muscle Shoals, Ala. After the completion of this dam, the manipulation of the water will be such as to render staff gauge readings at that point valueless, and the installation of an automatic gauge will become a necessity if the record, now the longest and most complete obtained on the Tennessee, is to be continued. The Chattanooga gauge, since 1913, has been in the pool created by the Hales Bar Dam, and although means have been devised to translate its present readings in terms of discharge, it has lost its erstwhile usefulness for such purposes. The Knoxville gauge, because of channel dredging and other local conditions, has never been considered satisfactory, and besides is likely to be drowned out by the construction of a proposed navigation dam below Knoxville. As it usually requires two or more years to obtain an accurate rating of a new gauge it will be plain that some foresight will have to be exercised in providing for the future continuity of stream flow records on the main stream.

Aside from their value in these studies, stream-flow data are of more or less direct benefit to the public. Many forms of enterprise are dependent upon this class of information for planning large expenditures in an intelligent manner. Obviously, the usefulness and reliability of data of this kind depend in a large measure upon the length and continuity of records.

Illustrative of the value of stream flow records in promoting water-power development is the significant statement contained in a letter dated November 23, 1920, from James W. Rickey, hydraulic engineer for the Aluminum Co. of America, addressed to the district engineer at Chattanooga, as follows: "Had it not been for the stream flow records that have been taken by the Government on the Little Tennessee River and its tributaries since 1898, it is doubtful if our company would have undertaken this pretentious development." The gauges referred to are those at Judson, N. C., on the Little Tennessee, and Bryson, N. C., on the Tuckasegee, established by United States Geological Survey in 1896 and 1907, respectively. The Aluminum Co. established a number of additional gauges in 1912, but relied primarily upon these older records as a basis for planning water power developments calling for the expenditure of many millions of dollars. In a similar way the early records obtained at Morgantown, Ga., on Toccoa (Ocoee) River, disclosed to the engineers of the Tennessee Power Co. the water-power possibilities that existed on that stream. This company now maintains five gauges on this stream in cooperation with the Geological Survey.

Information relating to rainfall in the Tennessee Basin is not extensive and in some sections is decidedly meager. This is due in no small measure to difficulty in securing reliable observers in some localities, and this is especially true of the high mountain sections. The amount and seasonal distribution of rainfall varies considerably, according to the location of the rain gauges; that is, whether on the windward or leeward sides of a mountain with respect to the direction of prevailing rain-bearing winds. This accounts for the comparatively light annual precipitation recorded at some localities situated at high altitudes, as, for instance, in the case of Asheville, N. C., which has an average annual rainfall of only 39.6 inches, although at an elevation of 2,255 feet, while Hendersonville, N. C., situated only 20 miles to the southeast, at an elevation of 2,167 feet, has an annual total of 61.4 inches. At many points in the Blue Ridge the mean annual rainfall amounts to over 80 inches, which is greater than any recorded elsewhere in the eastern half of the United States. During some years as much as 100 to 110 inches and over falls at some of these stations. At Horse Cove, N. C., in 1906, 113.8 inches fell.

In Tables 27 to 36 are given the mean annual rainfall figures for the principal stations, grouped by drainage basins. For each station the maximum and minimum recorded annual rainfall and the year of its occurrence is indicated. Stations with less than five years of continuous records are not included, except where special reasons require it. There are now about 70 active stations in the basin. The location of the existing and abandoned stations is shown in Chart VII.

Roughly stated, the mountain sections along the eastern edge of the basin have a rainfall of about 65 inches, the northern portion of the basin averages about 48 inches, while in the main valley 50 inches and over is common. It is an interesting fact that the western section of the Tennessee Basin, although the lowest in altitude, receives an annual precipitation exceeding by 2 or 3 inches that falling in the northern portion, exclusive of the Blue Ridge. The average annual rainfall for the entire basin, as computed in Table 37, is 51.6 inches. Distributed by seasons, this is accounted for approximately as follows: In the winter season, 13 inches; spring, 15 inches; summer, 14 inches; autumn, 9 inches. The month of greatest rainfall at most points in the basin is March. In the Asheville district it is July. In an average year there are 120 days with rain.

There is good reason to believe that, because of lack of data at high elevations, the averages for the French Broad, Little Tennessee, and Hiwassee Rivers, as given in Table 37, are too low, and that, therefore, the grand average for the entire basin as there given is slightly less than the true amount.

For such studies of water supply as are likely to be required in connection with the proposed survey, additional information on rainfall is highly desirable, particularly in those sections of the basin where local topographic conditions exert pronounced modifying influences.

TABLE 27.—*Precipitation in or near the drainage basin of Clinch River.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Kingston, Tenn.....	751	1884-1920	59.72	1889	37.92	1904	50.51	27
Clinton, Tenn.....	800	1884-1920	63.42	1909	38.27	1894	51.80	30
Harriman, Tenn.....	841	1891-1911	68.08	1897	42.55	1904	51.17	12
Crossville, Tenn.....	1,850	1912-1920	59.04	1917	47.30	1919	54.67	7
Springdale, Tenn.....	1,058	1888-1911	58.75	1901	38.56	1894	48.31	14
Tazewell, Tenn.....	1,350	1893-1920	60.11	1909	40.25	1904	59.43	22
Speers Ferry, Va.....	1,221	1896-1920	59.04	1906	38.69	1916	49.20	24
Big Stone Gap, Va.....	1,540	1891-1911	59.96	1907	39.06	1904	50.59	22
Burkes Garden, Va.....	3,250	1896-1920	63.71	1901	40.45	1910	48.42	20
Elk Knob, Va.....	3,243	1903-1920	56.11	1911	41.98	1914	48.95	16
Average annual rainfall.....							51.30	.....

TABLE 28.—*Precipitation in or near the drainage basin of Holston River.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Knoxville, Tenn.....	977	1854-1920	62.53	1884	35.09	1904	48.27	50
Jefferson City, Tenn.....	1,117	1910-1920	55.27	1917	36.42	1910	46.06	10
Rogersville, Tenn.....	1,150	1883-1920	53.84	1901	36.44	1895	42.55	34
Johnson City, Tenn.....	1,700	1883-1920	52.69	1901	32.54	1911	43.24	19
Bluff City, Tenn.....	1,400	1895-1920	51.51	1901	33.52	1904	43.13	22
Elizabethton, Tenn.....	1,575	1869-1920	55.70	1872	36.00	1911	43.18	25
Bristol, Tenn.....	1,676	1894-1908	54.24	1901	30.69	1904	41.06	15
Marion, Va.....	2,124	1884-1911	51.74	1899	33.58	1887	43.86	11
Mountain City, Tenn.....	2,486	1897-1920	68.27	1901	34.16	1915	46.94	19
Cane River, N. C.....	.....	1914-1918	47.79	1915	43.29	1914	45.15	3
Mendota, Va.....	1,350	1911-1918	51.31	1911	45.26	1916	48.25	8
Altapass, N. C.....	2,629	1914-1920	75.05	1916	44.80	1918	56.44	3
Linville, N. C.....	3,800	1891-1906	71.05	1898	50.15	1904	59.36	8
Banners Elk, N. C.....	3,750	1914-1920	64.12	1918	43.88	1917	55.33	6
Average annual rainfall.....							47.35	.....

TABLE 29.—*Precipitation in or near the drainage basin of French Broad River.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Knoxville, Tenn.....	977	1854-1920	62.53	1884	35.09	1904	48.27	50
Jefferson City, Tenn.....	1,117	1910-1920	55.27	1917	36.42	1910	46.06	10
Dandridge, Tenn.....	1,050	1905-1920	57.71	1917	38.36	1913	45.68	12
Newport, Tenn.....	1,100	1888-1920	55.43	1909	36.51	1919	43.96	27
Sevierville, Tenn.....	900	1906-1920	54.91	1907	41.79	1910	47.96	14
Greenville, Tenn.....	1,581	{1867-1906 1916-1920}	59.41	1886	36.10	1889	42.95	25
Birdsbridge, Tenn.....	1,300	1906-1915	48.44	1908	37.88	1914	43.72	3
Jonesboro, Tenn.....	1,740	1883-1908	52.69	1901	38.50	1904	45.22	10
Hot Springs, N. C.....	1,326	1906-1920	51.74	1908	34.19	1919	42.25	13
Marshall, N. C.....	1,646	1898-1920	52.11	1901	31.15	1910	40.45	15
Asheville, N. C.....	2,255	1902-1920	51.08	1918	30.07	1904	39.62	17
Hendersonville, N. C.....	2,167	1890-1920	92.60	1901	40.96	1904	61.41	21
Blantyre, N. C.....	1,900	1914-1917	74.37	1916	59.01	1914	66.21	3
Brevard, N. C.....	2,230	{1883-1885 1902-1920}	101.42	1906	39.87	1904	65.52	10
Waynesville, N. C.....	2,792	1894-1920	59.84	1901	26.66	1904	46.94	20
Linville, N. C.....	3,800	1891-1906	71.05	1898	50.15	1904	59.36	8
Average annual rainfall.....							49.10	.....

TABLE 30.—*Precipitation in or near the drainage basin of Little Tennessee River.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
McGhee, Tenn.....	850	1905-1920	55.86	1906	40.29	1910	48.12	15
Tellico Plains, Tenn.....	900	1896-1909	69.52	1901	41.06	1904	53.16	12
Rabun Gap, Ga.....	4,717	1878-1888	83.38	1879	49.05	1883	68.98	6
Bryson City, N. C.....	2,000	1887-1920	63.77	1901	39.34	1904	53.35	31
Cullowhee, N. C.....	2,100	1914-1920	53.79	1918	38.03	1919	46.29	6
Horse Cove, N. C.....	2,800	1891-1908	113.85	1906	62.87	1896	81.55	17
Average annual rainfall.....							58.58	.....

TABLE 31.—*Precipitation at stations in drainage basin of Hiwassee River.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Charleston, Tenn.....	709	1884-1920	70.23	1909	36.89	1904	53.62	21
Benton, Tenn.....	880	1883-1914	65.75	1901	36.75	1894	51.06	23
Murphy, N. C.....	1,614	{1872-1884 1888-1920}	84.80	1875	37.94	1915	57.92	39
Diamond, Ga.....	2,020	1889-1912	101.57	1889	48.00	1904	65.25	16
Average annual rainfall.....							56.96	.....

TABLE 32.—*Precipitation at stations in the valley of the main Tennessee River, upper section.*

Location.	Elevation (feet).	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Knoxville, Tenn.....	977	1854-1920	62.53	1884	35.09	1904	48.27	50
London, Tenn.....	816	1884-1920	58.76	1919	42.78	1889	50.65	16
Kingsport, Tenn.....	751	1884-1920	59.72	1889	37.92	1904	50.51	27
Decatur, Tenn.....	850	1895-1920	70.66	1903	39.67	1904	55.42	18
Charleston, Tenn.....	709	1884-1920	70.23	1909	36.89	1904	53.62	21
Lookout Mountain, Tenn.....	2,148	1914-1920	59.60	1915	47.42	1914	54.59	4
Chattanooga, Tenn.....	808	1879-1920	67.97	1880	32.68	1904	50.32	36
Average annual rainfall.....							51.46	.....

TABLE 33.—*Precipitation at stations in drainage basin of Elk River.*

Location.	Elevation (feet).	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Loretto, Tenn.....	774	1916-1920	67.60	1919	50.95	1918	57.55	3
Yukon, Tenn.....	850	1896-1920	67.73	1911	38.68	1904	52.85	23
Sewanee, Tenn.....	1,950	1895-1920	66.81	1917	41.36	1904	53.78	25
Tullahoma, Tenn.....	1,075	1883-1920	66.68	1884	42.04	1914	53.18	31
Average annual rainfall.....							54.34	.....

TABLE 34.—*Precipitation at stations in the valley of the main Tennessee River, middle section.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Bridgeport, Ala.....	660	1896-1920	71.93	1920	39.09	1904	52.91	24
Scottsboro, Ala.....	652	1882-1920	69.49	1892	40.96	1896	52.86	34
Decatur, Ala.....	573	1879-1920	64.87	1911	34.70	1904	49.05	37
Florence, Ala.....	563	1884-1920	63.18	1892	40.68	1898	50.03	32
Tuscumbia, Ala.....	488	1882-1920	67.49	1892	40.62	1904	48.66	34
Guntersville, Ala.....	580	1905-1920	63.79	1918	45.95	1914	54.68	11
Madison, Ala.....	573	1894-1920	69.09	1911	37.90	1902	50.02	22
Riverton, Ala.....	360	1897-1920	62.04	1902	42.14	1899	51.83	19
Average annual rainfall.....							51.25	.....

TABLE 35.—*Precipitation in or near the drainage basin of Duck River.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Pinewood, Tenn.....	520	1914-1920	70.05	1919	37.54	1918	47.97	7
Hohenwald, Tenn.....	983	1883-1920	74.26	1919	40.63	1895	54.29	36
Ashwood, Tenn.....	725	1873-1920	66.05	1882	52.43	1901	49.74	47
Lynnville, Tenn.....	770	1889-1920	65.34	1912	40.61	1904	53.99	32
Lewisburg, Tenn.....	727	1888-1920	62.81	1905	37.42	1904	52.11	24
Palmetto, Tenn.....	770	1883-1920	65.37	1912	40.46	1904	51.11	29
Tullahoma, Tenn.....	1,075	1883-1920	66.68	1884	42.04	1914	53.18	31
Waynesboro, Tenn.....	753	1884-1920	70.52	1919	37.47	1895	51.00	35
Average annual rainfall.....							51.67	.....

TABLE 36.—*Precipitation at stations in the valley of the main Tennessee River, lower section.*

Location.	Elevation, feet.	Period of record.	Maximum.		Minimum.		Mean, inches.	Number of years.
			Inches.	Year.	Inches.	Year.		
Savannah, Tenn.....	442	1883-1920	66.52	1890	39.15	1895	50.80	37
Corinth, Miss.....	470	1894-1920	65.39	1911	36.20	1896	50.84	25
Waynesboro, Tenn.....	753	1884-1920	70.52	1919	37.47	1895	51.00	35
Springville, Tenn.....	377	1903-1920	70.47	1919	37.10	1904	50.39	17
Perryville, Tenn.....	387	1896-1920	66.71	1912	37.17	1903	49.61	20
Johnsonville, Tenn.....	364	1883-1920	75.80	1919	35.42	1894	49.16	36
Average annual rainfall.....							50.52	.....

TABLE 37.—*Summary of precipitation in drainage basin of Tennessee River.*

Stream.	Drainage area.	Mean annual precipitation.	Stream.	Drainage area.	Mean annual precipitation.
	<i>Square miles.</i>	<i>Inches.</i>		<i>Square miles.</i>	<i>Inches.</i>
Chinch River.....	4,420	51.30	Middle section Tennessee Valley.....	8,300	51.25
Holston River.....	3,860	47.34	Duck River.....	3,640	51.67
French Broad River.....	5,130	49.10	Lower section Tennessee Valley.....	5,130	50.52
Little Tennessee River.....	2,650	58.58			
Hiwassee River.....	2,720	56.96			
Upper section Tennessee Valley.....	2,950	51.46	Tennessee River.....	40,800	51.62
Elk River.....	2,000	54.34			

FLOODS AND LOW-WATER FLOW.

The Tennessee is subject to sudden and frequent fluctuations in discharge. Its headwaters drain a mountainous region noted for heavy and prolonged rains and generally high annual precipitation. The high-water season is in the late winter and early spring and is caused by copious rainfalls, while the melting of snow as a contributive factor is only of minor significance. In ordinary years all snow disappears before the higher flood stages occur. Throughout the months of February, March, April, and May a succession of floods is a matter of common occurrence. Flood stages are not confined to those months, however, and though much less frequent at other times, may happen at any time of the year. The floods of September, 1898, July, 1916, and August, 1920, are instances of high stages in what normally is the low-water season. These are not, however, extraordinary occurrences.

Inundations resulting from winter and spring floods take place, as a rule, before the crop growing season and therefore cause but little loss to the farmers, while city property for the most part is on sufficiently elevated ground so as to be out of reach of all but the extraordinary flood stages. Summer and fall floods, on the other hand, cause much damage to crops.

Indicative of the troublesome character of the Tennessee stands out the fact that, unlike other rivers of similar size, no railroads and highways are found paralleling its banks. Towns and cities on the Tennessee are few in number and built for the most part on high ground. Between Knoxville and Chattanooga, a distance of 188 miles by river, only two railroad bridges cross the river and there is not a single highway bridge. In the entire course of 645 miles of main river there are only 3 localities where highway bridges span it.

Chattanooga is the only large city on the river that is affected seriously by floods, and no material damage results there below a stage of 45 feet. Above that stage water enters the low portions of the business section and interferes with railroad operation. A stage of 45 feet or more has occurred three times within the last 50 years. Since high water troubles at Chattanooga are primarily the result of backwater from the Tennessee extending up certain creeks, the situation is not readily remedied. To date no protection of any sort has been provided, but a costly levee system has been proposed.

As to whether or not flood stages are increasing or decreasing either in frequency or in height can not be definitely determined from existing data. Table 38 shows the occurrences of extreme high and low water stages in the Tennessee at Florence, Ala., for the entire period during which daily gauge height observations have been taken.¹ No well-defined or steady change is noticeable, but there appears to be a tendency toward decrease in the frequency, height, and duration of great floods, to which attention was directed in 1911 by Col. Wm. W. Harts in his report on the Tennessee River, House Document 360, Sixty-second Congress, second session, page 42. The 49-year record in Table 38 furnishes, however, no safe criterion in this regard, for it has been found on other rivers that it requires a record of a century and preferably longer to establish conclusively the rates of change in the flood characteristics of a large stream. Changed run-off conditions caused by deforestation,

¹ In the preparation of Table 38, the latest rating table was used, giving the relation between stages and discharge at the Florence gauge. This rating table is based on the measurements of flow made at Florence by the Engineer Department and the Geological Survey, and has recently been checked by a series of discharge measurements made by Hugh L. Cooper & Co. This will account for the variation between the figures in this table and in a similar one published by Maj. H. Burgess on page 132 of H. Doc. 1222, 64th Cong., 1st sess.

extensive cultivation, municipal works, drainage, and river improvements have doubtless caused noticeable changes in the extreme high and low water occurrences of certain smaller streams tributary to the Tennessee, but such changes are thus far too trivial and local to affect sensibly the behavior of the main river.

TABLE 38.—*Occurrence of high and low stages on the Tennessee River at Florence, Ala., 1872–1920.*

Water year ending Sept. 30.	Number of days discharge was below and above quantities shown.					
	Below 8,500 second-foot, stage -0.5.	Below 10,000 second-foot, stage -0.2.	Above 200,000 second-foot, stage 17.25.	Above 250,000 second-foot, stage 20.4.	Above 300,000 second-foot, stage 23.5.	Above 350,000 second-foot, stage 26.6.
1872.....	0	11	0	0	0	0
1873.....	13	31	17	11	0	0
1874.....	0	15	31	14	6	0
1875.....	0	0	36	27	15	10
1876.....	1	16	5	0	0	0
1877.....	3	7	7	0	0	0
1878.....	0	15	10	2	0	0
1879.....	0	10	16	11	3	0
1880.....	0	0	1	0	0	0
1881.....	0	0	38	21	15	8
1882.....	0	0	10	0	0	0
1883.....	0	0	38	26	10	0
1884.....	0	0	5	0	0	0
1885.....	0	0	17	16	13	5
1886.....	0	0	8	0	0	0
1887.....	0	0	8	1	0	0
1888.....	0	0	7	0	0	0
1889.....	0	0	11	10	0	0
1890.....	0	0	26	18	0	0
1891.....	0	0	16	9	2	0
1892.....	0	0	9	4	0	0
1893.....	0	0	1	0	0	0
1894.....	0	0	5	0	0	0
1895.....	0	0	21	15	9	4
1896.....	0	17	0	0	0	0
1897.....	0	0	24	13	6	0
1898.....	0	0	4	0	0	0
1899.....	0	0	5	0	0	0
1900.....	0	0	18	4	0	0
1901.....	0	6	12	0	0	0
1902.....	0	21	0	0	0	0
1903.....	0	20	0	0	0	0
1904.....	0	0	0	0	0	0
1905.....	0	0	0	0	0	0
1906.....	0	0	0	0	0	0
1907.....	0	0	0	0	0	0
1908.....	0	0	9	0	0	0
1909.....	0	0	0	0	0	0
1910.....	0	1	9	5	0	0
1911.....	0	0	14	0	0	0
1912.....	0	6	6	0	0	0
1913.....	4	34	2	0	0	0
1914.....	0	20	1	0	0	0
1915.....	0	0	12	0	0	0
1916.....	0	0	30	13	3	0
1917.....	0	7	9	4	0	0
1918.....	6	28	6	0	0	0
1919.....	0	0	14	10	0	0
1920.....	0	0	0	0	0	0
Total.....	27	274	518	234	82	27
Average per year.....	0.55	5.60	10.55	4.80	1.67	0.55

The maximum rates of flood flow in the Tennessee are not as high as might ordinarily be expected of a river basin subject to the high rates of storm rainfall that are common there. This is attributable to three factors: (a) The peculiar configuration of the drainage basin which near its middle is constricted to a width of less than 40 miles; (b) the general westerly flow of the river in a direction contrary to the movement of storms; (c) the arrangement of the tributaries, which does not favor rapid collection and concentration of run-off. This is well illustrated by a comparison of the greatest recorded floods from nearly equal areas drained by the Susquehanna, Ohio, and Tennessee Rivers, in the following table:

Stream.	Locality.	Drainage area (square miles).	Date of maximum flood.	Maximum rate of flood flow.	
				Second-feet.	Second-feet per square mile.
Susquehanna.....	Harrisburg, Pa.....	24, 100	June 2, 1889	700, 000	29. 1
Ohio.....	Wheeling, W. Va.....	23, 800	Feb. 7, 1884	494, 000	20. 8
Tennessee.....	Chattanooga, Tenn.....	21, 400	Mar. 11, 1867	393, 000	18. 4

The floods listed in each case represent the greatest of a century. It will be noted that the Susquehanna at Harrisburg discharges, per square mile of drainage area, 58 per cent more than the Tennessee at Chattanooga, and the Ohio at Wheeling 13 per cent more, although the mean annual flow of the Tennessee is greater than that of either the Susquehanna or the Ohio at the respective points named.

Because of the peculiar configuration of the drainage basin there is no direct relation between flood stages on the upper river and on its lower reaches. Thus, the highest flood on record at Decatur, Ala., and points upstream as far as Knoxville, Tenn., occurred in March, 1867, while at points downstream from Decatur the flood of March, 1897, was the greatest. The peak discharge in 1897 was 255,800 second-feet at Chattanooga, and 443,600 second-feet at Florence, Ala. The peak discharge in 1867 was 393,000 second-feet at Chattanooga, as against 421,000 second-feet at Florence. Table 2 in paragraph 4 of the report by Maj. Harold C. Fiske gives the maximum stages at eight localities for the five principal floods of which reliable records are available and illustrates this point more in detail.

The range between high and low water stages at various points on the river differs widely. At Chattanooga it is 58.6 feet. The greatest range before the completion of Hales Bar Dam was 70 feet at the "Suck" in the mountain section of the Tennessee, 13 miles below Chattanooga, where the channel is less than 400 feet wide at low water. The least range is 12.7 feet at Muscle Shoals, and is attributable to the long series of rapids and great width of channel in that locality.

No systematic study of the flood problem on the Tennessee and its larger tributaries appears to have been undertaken. Such data as are available are of a scattered nature and relate principally to dates and stages of the recorded floods. On the main stream a few long records of river stages, coupled with stream-flow measurements made by the Geological Survey, Corps of Engineers, and Mississippi River Commission afford a fair basis for detailed study, but this needs to be supplemented with data on storm rainfall and early floods before any reliable conclusions can be drawn as to the genesis and periodicity of great floods. It is known in a vague way that great floods occurred prior to 1847. Efforts should be made to determine the approximate heights of these floods, and also of any others that took place before regular river stage observations began, in order that as much light as possible may be had on flood frequencies.

The Weather Bureau official at Chattanooga has gathered considerable information for his use in flood forecasting, but this data is of a specialized nature and only of indirect value in studying the practicability of lowering flood crests. He states that the main flood crest in the Tennessee above Chattanooga is caused by that of the Clinch River, and that there is little synchronism in the arrival of the flood crests from the other tributaries.

Practically nothing is now known with regard to the acreage of valley lands flooded at the higher stages, or as to the quantity of water temporarily so stored on the overflowed lands. No estimate can, therefore, be made at this time as to the amount of artificial storage that would be needed to produce any effective reduction in depth of overflow or as to the practical heights of levees required at any locality. Little is known as regards the time of arrival into the parent stream of the flood crests from its principal tributaries during storms covering the major part of the basin; no intelligent estimates, therefore, can be made at this time as to where storage works on the watershed should be located so as to be most effective in breaking up synchronism, if any, in such time of arrival.

No statistical data is available showing the monetary losses at various localities for any given flood stage, and hence, there is no index as to what may be considered a reasonable expenditure for eliminating future damage of this kind, in whole or in part, for any given locality. On the whole, the character and infrequency of great flood damage appear to be such that it is doubtful whether costly works for the sole purpose of providing flood control will be warranted anywhere in the valley. The

indications are that flood reduction on the Tennessee will have to be in large measure a by-product of canalization and water-power development. How appreciable a reduction may be obtainable through these agencies is worthy of the most careful investigation. The large amount of hydrographic and hydrologic data already at hand, if properly brought up to date and supplemented by accurate surveys and stream flow measurements, will make it possible to forecast with considerable certainty what may be expected in that direction.

As regards extreme low-water flow, an inspection of Table 38 shows no marked tendency toward either increase or decrease in stage, frequency, or duration. When the gauge at Chattanooga was first established in 1874 its zero was set to correspond to the low-water stage of September 1839, at that time considered the minimum on record. The river since that time has never fallen below that level, although it descended to that stage on September 11 to 14, 1881, and again on September 19, 1883, when the discharge was 4,800 cubic feet per second. The minimum stage observed at Florence, -0.8 foot, occurred October 24, and 26 to 29, 1872, and again on September 18, 1878, when the discharge amounted to about 7,000 cubic feet per second. At Knoxville the lowest stages appear to have occurred in 1904, when the discharge fell to 1,750 cubic feet per second; similar low stages are said to have occurred in 1871 and 1884, but the record there is not as reliable as at Chattanooga and Florence.

The foregoing illustrates that, as in the case of the maximum flood stages, there is no immediate relation between the minimum stages on the upper and lower sections of the main river, due evidently to differences in rainfall over the various parts of the drainage basin.

The year 1904 was the one of smallest total discharge, the average flow for the entire year being approximately half that for a normal year. It was followed by two other lean years. Another series of dry years occurred in 1894, 1895, 1896, and 1897. These two periods may be looked upon as affording safe criterions for planning hydraulic works in the Tennessee basin involving storage. In Table 39 are shown the minimum recorded discharges for some of the principal tributaries, at points where observations have been in progress for some years. Marked variation will be noted in the minima per square mile of drainage area in different parts of the basin. It is as yet premature to assign any specific reasons for such variations. The low water conditions on the individual tributaries have received little study in the past except in the case of the Little Tennessee and Hiwassee Rivers. Much information is needed on this general subject in order to determine intelligently the hydroelectric possibilities on the tributaries.

TABLE 39.—Minimum recorded flow of tributaries of Tennessee River.

Stream.	Station.	Period of record.	Drainage area.	Minimum recorded flow.		Date of occurrence.
				Second-feet.	Second-feet per square mile.	
			<i>Sq. Mi.</i>			
Clinch.....	Clinton, Tenn.....	1900-1920	2,750	450	0.16	{1900-1903 1904-1909 1910
South Fork Holston..	Bluff City, Tenn.....	1900-1920	828	150	.18	1904
Holston.....	Rogersville, Tenn.....	1902-1920	3,060	490	.16	1904
French Broad.....	Asheville, N. C.....	1895-1920	987	380	.39	1907
		1900-1901				
Big Pigeon.....	Newport, Tenn.....	{1903-1905 1906-1909 1918-1920	655	102	.21	1919
		1903-1908				
Nolichucky.....	Greenville, Tenn.....	{1918-1920	1,100	320	.28	1904
Tuckasegee.....	Bryson, N. C.....	1897-1920	662	300	.45	1899
Little Tennessee.....	Judson, N. C.....	1896-1920	675	275	.41	1904-1905
Do.....	McGhee, Tenn.....	{1904-1914 1918-1920	2,470	750	.30	1904
Hiwassee.....	Murphy, N. C.....	1896-1920	410	140	.34	1914
Valley.....	Tomotia, N. C.....	{1904-1909 1914-1920	120	22	.18	1904
		1901-1905				
Nottely.....	Ranger, N. C.....	{1914-1920	272	89	.33	1914-1915
		1900-1913				
Hiwassee.....	Reliance, Tenn.....	{1918-1920	1,180	380	.32	1904

PRESERVATION OF REGIMEN.

The channel of the Tennessee in the past has been remarkably free from shifting, bar formation, and other *débris* accumulations. Channel surveys and soundings made by the Engineer Department at intervals over long periods of years furnish abundant evidence on this score, and show that there exists a fair state of equilibrium in the regimen of the Tennessee, especially in the upper and middle sections of the main stream. This is the more significant since nearly all of the tributary streams are actively engaged in eroding their beds, and drain regions of considerable declivity where constant natural surface erosion has been in progress for ages and where now this surface erosion has in many instances become accelerated as the result of devegetation. The main river is evidently capable of transporting all of the erosion *débris* delivered into it by the tributaries, but does not appear to be eroding its own channel appreciably.

This state of equilibrium is of the greatest importance and should be given due cognizance in any considerations pertaining to the utilization of the river for the purposes of man. Any form of utilization is likely to modify to some extent existing conditions of equilibrium, but if wisely carried out will not necessarily upset it. To completely regulate the flow of a river like the Tennessee so as to make it uniform the year round, if such a thing were possible, would be on a par with building a sewer system without provision for flushing. What the intermittent discharge from a flush tank does for a sewer, flood flow does for a river. In short, while the desirability of diminishing floods is unquestioned, their complete elimination would prove a detriment rather than a benefit. As will appear from the discussion of floods elsewhere in this report, some reduction of high flood stages in the Tennessee will probably come about as the result of the extensive utilization of the river and its tributaries for navigation and power purposes, though it is not likely to be of sufficient magnitude as to affect the regimen of the Tennessee to any great extent. Nevertheless, the subject is of an importance which seems to demand careful determination as to what ultimate reduction in flood flow is permissible with safety, or otherwise stated, as to what rates and frequencies of flood flow are requisite in order that the river shall continue to maintain proper channel conditions.

Of recent years the destruction of vegetation over large areas along the upper Ocoee River has resulted in soil wash from the hillsides, causing this stream to carry large volumes of earth and gravel which lodge in the reservoir maintained on that stream by the Tennessee Power Co., thereby tending to diminish its capacity. The conditions on the Ocoee were brought about by two agencies which for a time held sway uncontrolled, viz. Ruthless timber cutting and the liberation of sulphur fumes from copper reduction works. In sections the soil is so permeated with sulphuric acid as to prevent vegetable growth of any kind. Both agencies are now largely under control, and steps at reforestation have for some time been taken by the Forest Service.

The troubles on the Ocoee River fortunately are not typical of what is taking place in other parts of the basin where deforestation has occurred. On the headwaters of Holston and Clinch rivers, timber cutting has been complete over large areas and the forest has given place to extensive grazing lands and some agriculture. This is a rolling country with occasional steep slopes and little trouble is being experienced from hillside wash, the vegetation, especially in the form of grass sod, being adequate to prevent erosion. The streams in that part of the basin consequently are not burdened with *débris*. In the high mountain region on the headwaters of the Watauga, Doe, Nolichucky, and French Broad, a country of steep slopes, destructive lumbering and consequent increase in erosion have given rise to a coarser form of *débris* reaching the streams, and of late years floods have left deposits of gravel and cobbles on the alluvial lands bordering these streams. The appearance of these coarser materials has been interpreted¹ as indicating increased flood heights in the tributaries, although this does not appear to be substantiated by flood records. Whatever increases in flood height may have taken place in rivulets and mountain streams, the parent stream furnishes no evidence of such increases, and there is reason to believe that its regimen has not been sensibly affected by changed conditions in the comparatively small portions of the drainage basin referred to.

It is alleged that *débris* deposits are now making their appearance in the navigable portions of the river, but the information is by no means conclusive. It is conceivable that the scouring action of great floods may, in time, remove such deposits. At any rate, it would be premature to conclude that erosion has been accelerated in the

¹ Glenn, L. C., Denudation and Erosion in the Southern Appalachian Region, Professional Paper No. 72, United States Geological Survey.

Tennessee Basin to the extent where it is beginning to overtax the transporting capacity of the main river.

The removal of debris accumulations from impounding reservoirs presents a formidable problem, which up to the present time has defied any solution by simple or inexpensive methods. In the navigable portions of the Tennessee, however, no such problem has as yet presented itself, and it remains to be proven that, in the course of years, much trouble is likely to arise from that source. The only deposits that are now large enough to be noteworthy occur in the slack water immediately above navigation dams, and consist not only of materials transported during floods, but also of the finer materials carried in suspension during ordinary stages and which have settled out. Thus far such deposits have not interfered with navigation, and it is quite probable that the river may continue to maintain ample navigable depths in these localities in spite of such deposits.

Of special interest is the rapidity with which the lands submerged by the Hales Bar Dam are silting up. The prospects are that much of this land will be built up above the surface of the pool within the next five years and again become available for agriculture, better and richer than before the dam was built. The same process may take place on flowage lands above proposed dams elsewhere in the basin, especially where the depths of flooding are shallow, thus introducing a factor in the vexatious problem of flowage damages that hitherto has not received the consideration which obviously is due it. The rate at which flowage lands may be expected to revert to profitable farming areas is a matter that is worthy of determination in connection with the proposed survey.

The work that has been done by the Government in preserving the forests of the Appalachian region should be mentioned here, since the areas cover quite effectively some of the principal headwaters of the Tennessee, and if this work is extended along the lines originally laid down, permanent protection of a substantial character will result. Under the provisions of the "Weeks Law" of March 1, 1911, designed primarily for affording protection to the headwaters of navigable streams, the Federal Government has purchased outright about 470,000 acres of timber land within the drainage basin of the Tennessee (see Chart VIII). These purchases are mostly in the Unaka and Great Smoky Mountains, and in Tennessee are limited by legislative act to a strip not exceeding 20 miles in width along the North Carolina-Tennessee State boundary. This limitation renders it impossible at present for the Government to acquire forest lands along the Cumberland Plateau or in other sections of the Tennessee basin. As regards future purchases, the Acting Forester under date of November 24, 1920, advised the district engineer at Chattanooga as follows: "It is improbable that any lands in the basin of the Tennessee will be considered for purchase within the next five years outside of the limits of existing 'Purchase Areas' as shown in the report entitled 'Progress of Purchase of Eastern National Forests under the Weeks Law,' unless the situation with respect to erosion in that basin should make the extension of the National Forest area especially desirable."

The following has been compiled from the publication above referred to:

White Top purchase area (see Chart VIII), lies in Tennessee and Virginia and extends south of the South Fork of Holston River, but does not include Watauga River. Practically all of the area purchased, 69,200 acres, is on south fork drainage.

Unaka purchase area is situated in the Unaka mountains, along the Tennessee-North Carolina State line, and includes headwaters of Watauga, Doe, Nolichucky, and part of French Broad drainage. All of the 56,129 acres purchased is within the Tennessee River basin.

Boone purchase area, situated entirely in North Carolina, barely touches the headwaters of the North Toe. None of the 47,775 acres purchased are of benefit to Tennessee drainage.

Georgia purchase area lies nearly entirely within the State of Georgia, and covers the headwaters of Hiwassee and Ocoee (Toccoa) Rivers. Only Toccoa River is benefited by purchases, all of the 70,698 acres acquired lying within its watershed. Fifteen thousand and eighty acres were added to this during 1920.

Cherokee purchase area is entirely within the State of Tennessee and extends across Ocoee, Hiwassee, and Tellico Rivers north to Little Tennessee River. Areas purchased, amounting to 143,336 acres, are principally in the drainage of the Ocoee and Hiwassee, and include a small area on Tellico River.

Mount Mitchell purchase area, situated in North Carolina, covers the headwaters of South Toe, Ivy, and Swannanoa Rivers. At least half of the 89,795 acres purchased benefit the Tennessee River.

Pisgah purchase area is nearly entirely within the basin of the Tennessee, covering the headwaters of French Broad River and tributaries, and of Tuckasegee River. The 94,588 acres purchased are entirely in the watershed of the French Broad.

Savannah purchase area is in North Carolina, South Carolina, and Georgia, and a small portion covers the headwaters of Little Tennessee River. Probably not over 30,000 of the 153,202 acres purchased lie in Tennessee drainage.

Nantahala purchase area includes principally drainage of Nantahala and Cheoah Rivers and small portions of Hiwassee drainage and tributaries of Little Tennessee River. Most of the 87,907 acres purchased is on the Nantahala watershed.

The entire subject of Tennessee River regimen and all the factors that are likely to affect it, merit most impartial analysis and investigation. There is reason to believe that the serious consequences of denudation that have manifested themselves in the river basins east of the Blue Ridge, and also in the Ducktown region on Ocoee River, have been the cause of much alarm lest a similar calamity should befall other portions of the Tennessee River Basin. To what extent such alarm is justified is not at all clear from available facts, and this emphasizes the need of further dispassionate study. Obviously there is as much danger of overestimating the importance of temporary deposits in streams, subject to removal in the next great flood, as there is danger of underestimating the importance of small but steadily-growing deposits of a permanent character, which in time might decrease the normal carrying capacity of the river channel.

WATER POWER.

The facts set forth elsewhere in this report relating to rainfall, stream flow, and topography make it obvious that the natural physical conditions in the Tennessee River Basin are peculiarly favorable to the development of water power on a large scale. On account of the mild winters, ice troubles, so common at hydroelectric plants in the northern United States and Canada, are rare and become a negligible factor in the operation of such installations in this region. The present status of electric power development in the Tennessee basin is shown in Chart V on which are indicated all of the principal hydroelectric, and some of the more important steam plants, and also the main transmission lines.

The more important hydroelectric plants afford excellent illustration of the advantages that accrue from combinations of high-head installations on the mountain streams with low-head installations on the main river or lower reaches of its principal tributaries. Such combinations are seldom feasible on streams farther north but are a noteworthy feature of the power possibilities of the Tennessee River and of a few other southern rivers. The logical type of low-head development is exemplified by that at Hales Bar. (No. 6, Chart V.) Here a 40-foot dam built for the improvement of navigation through the dangerous "mountain section" of the Tennessee River below Chattanooga, furnishes a head of about 37 feet at ordinary low stages. This head varies, of course, inversely with the flow of the river, increasing to 39.5 feet during extreme low flows (corresponding to less than 5,000 cubic feet per second) and decreasing to less than 19 feet at high-water stages. During flood flows of 250,000 cubic feet per second and over no power is generated, but this condition occurs rarely and then only over short periods. The installed capacity is 62,000 horsepower consisting of 14 units, and power is transmitted at 66,000 and 120,000 volts.

Opportunities for constructing similar installations exist at several points on the main river where navigation dams ranging in height of from 30 to 50 feet are feasible. An exceptional opportunity presented itself at Muscle Shoals, where the river has a fall of 134 feet in a distance of 38.5 miles, of which 80 feet occurs in 13 miles. It is here that the Wilson Dam (No. 7 in Chart V) is being built to create a head of about 96 feet and utilize a flow rarely falling below 10,000 cubic feet per second. Considering the size of the Tennessee River at this point, both as regards discharge and the 30,000 square miles of drainage area, this site, in many respects stands out unique among the larger water powers of the United States.

It should be noted that at main river plants, as here described, the demands of navigation and the character of the river flow are such as to effectually preclude the use of any stored water. On the mountain streams, on the other hand, storage sites abound. On these streams high-head developments utilizing small flows of water, amplified during low stages by drawing on storage reservoirs, find ready application. According to the conditions to be met, either high dams, or low diverting dams with long flumes or tunnels, or combinations of both these types may be found possible. The range of head obtainable varies considerably. Plant No. 1 at Parksville, Tenn., of the Tennessee Power Co., on Ocoee River, utilizes a head of 80 feet with a dam 110 feet high; plant No. 2 of that company has a head of 255 feet obtained by means of a 30-foot diverting dam and a flume 5 miles in length. Among the projected plants of the Aluminum Co. of America, on the Little Tennessee River and its tributaries, are heads as high as 600 and 900 feet.

It is a noteworthy fact, however, that some of the tributaries of the Tennessee, even in the high mountain districts, have comparatively little fall. Thus, the Clinch, Holston, and French Broad Rivers, have over large parts of their courses less than 5 feet of fall per mile. Such sections may offer good sites for the storage of water, but it remains to be demonstrated whether high-head hydroelectric installations can be created on them at reasonable cost.

The possibilities for future development in the Tennessee basin are shown in Chart VI, in which each circle represents a site at which a large amount of potential power is available. Except in some cases in which surveys and estimates have been made, comparatively little is known regarding these sites. A discussion of the more important sites is contained in Appendix B. It will be noted by reference to Chart VI that the proposed plants on the tributaries outnumber by far those on the main stream. Until further studies are made it will be impossible to say what the proportion of high-head to low-head plants should be, if indeed any such proportion can be arrived at.

Practically no information is at hand regarding the multitude of water powers of the milldam type found in this region. These are principally on the smaller streams and utilize, as a rule, very low heads. The power obtained is of an intermittent character not adapted to public service. This type of development is not under consideration in this report and no attempt has been made to show the location of such installations in Chart V.

The effect which water-power development on the tributaries is likely to have on the water supply of the navigable river portions is worthy of most careful analysis. It is believed that successions of large water power developments carried out on any mountain stream and its tributaries will not only tend to regulate the flow of such stream and be a benefit to the development of its power, but will prove of decided benefit to both navigation and hydroelectric development on the navigable portions below. The effect on the water supply of the lower section of the Tennessee River, where open-channel navigation exists, it is believed will also be greatly improved by the use of water for power production on the upper tributaries. The Tennessee Power Co. installations, existing and projected, when carried to completion, will effect a fair degree of equalization of the flow of the Ocoee River. Likewise, the proposed plants of the Aluminum Co. will do much toward regulating the flow of the Little Tennessee River. This subject will bear considerable study in connection with flood amelioration.

Other things being equal, the successful development of water power in the Tennessee basin appears to be contingent, in large measure, on proper interconnection of the various installations. This is demonstrated by the present method of interoperation of the various power plants of the Tennessee Power Co., and the Chattanooga & Tennessee River Power Co., in which the low-head plant on the main stream at Hales Bar is operated as a base-load plant, while the high-head plants on the mountain stream serve as peak-load plants. During the high-water season the high-head plants operate under favorable conditions while the low-head plants suffers from greatly reduced head; during the low-water season the latter plant operates under maximum head while the high-head plants are likely to be short of water unless provided with abundant storage. A number of other well-known advantages accrue from such interconnection, but an enumeration thereof does not appear desirable here. There is, however, a limit to such exchange and supplementing of power, for during protracted low stages both high and low head plants usually run short of water and find it difficult to supply their market requirements. During the fall of 1920, several industries in Chattanooga, dependent upon power from hydroelectric plants, were compelled to operate at considerably reduced capacity for a period of about two months because of lack of power caused by extreme low water. In 1919 a similar condition existed over a shorter period of time. During eight months of the year, however, there is at the present time power in excess of market demands in the region supplied by these companies.

In Chart V are shown the existing transmission systems and their interconnection. The trunk lines connecting Parksville with Chattanooga, Nashville, and Knoxville, each carry 120,000 volts. The Cheoah plant of the Aluminum Co. of America (see No. 4 in Chart V) transmits power to the reduction works at Alcoa at 160,000 volts and higher. The smaller systems use voltages ranging from 6,600 to 66,000.

Interconnection with hydroelectric systems situated on the Atlantic Coast streams of North and South Carolina, and Georgia, and in the Gulf drainage in Alabama, appears to present decided advantages aside from the diversity factor so introduced, because the fluctuations in flow of these rivers, as a rule, do not synchronize with those in Tennessee basin streams. A comparison of the hydrographs of the two systems of streams reveals that, because of differences in rainfall distribution to the east and west of the mountains the respective high and low water periods in the several river

systems seldom coincide. This is especially true of the summer flow. But even this kind of interconnection will not entirely supplement the shortage of water during extreme low-water seasons. For overcoming the latter difficulty either large amounts of storage will have to be provided to be drawn upon during such seasons, or steam plants for furnishing auxiliary power must be provided at points where coal can be had at low cost. As regards providing such storage, the experience on North Carolina streams has not been encouraging because of the large volumes of sand and gravel carried by these streams and the consequent tendency to reduce reservoir capacity by silting. The indications are that less trouble from that source will be experienced in the Tennessee basin where timber cutting has resulted in comparatively little denudation, and where the soil is not as easily eroded as it is east of the mountains. The silting of the reservoir of the Tennessee Power Co. on Ocoee River, referred to elsewhere in this report, is caused by unusual and localized conditions not likely to be duplicated on other Tennessee basin streams. Topographic conditions are favorable for creating storage on many of the tributaries of the Tennessee, but careful surveys and geological studies are needed to locate the best sites. The feasibility of providing steam auxiliaries of large capacity is also worthy of careful study, the existence of large coal fields in the Tennessee basin presenting many advantages in that direction.

It will be noted by reference to Chart V that interconnection of transmission systems has already been effected in the southern portion of the basin where the Tennessee Power Co. system has connection at Cartersville, Ga., with the lines of the Georgia Railway and Power Co., which in turn are connected with the Southern Power Co. system to the east and with the Alabama Power Co. system to the west. In the northern part of the basin practically no interconnection exists at present, although the distances between the various systems are not great. The amount of power that can be exchanged by the connection to the south is not at present large, but it is indicative of the growing appreciation of the value of interconnection. As additional power plants are built and existing transmission systems extended in the Tennessee basin, the time will come when a superpower system will eventually become possible. Any studies that may be made of the water-power situation in connection with the proposed survey would hardly be complete without taking cognizance of this ultimate possibility.

The commercial feasibility of water power development in general hinges materially on first cost and the character of the power market to be served. In the Tennessee basin the cost of acquiring lands and rights of way, usually the largest single item in first cost of hydroelectric development, may not prove as much of an obstacle as it has elsewhere in the United States, for railroads hug the streams only in few cases, settlement, as a rule, is sparse, and the land is only partly in high state of cultivation. Existing laws, on the whole, are favorable to undertakings of this kind.

The market for power must of necessity be a matter of future growth. If the past may be taken as at all indicative of what may be expected to come, the prospects for selling power in large quantities at high load factor are perhaps exceptional in the Tennessee basin. Load factors ranging from 60 to 82 per cent, as reported by existing plants result not only from interconnection, but reflect the nature of some of the principal loads carried, namely, electrochemical processes which couple high-demand rates with study usage throughout the 24 hours. The Aluminum Co. of America reports the unusual load factor of 97 per cent.

The rapidly increasing use of electric-furnace methods, together with the existence of large bodies of various minerals in the region of the Tennessee, point to a possible future market for hydroelectric power that, because of its attractiveness, merits most careful study. Since 1916 the number of electric furnaces in the United States has more than doubled and at the time of submitting this report is in the neighborhood of 765, representing a possible connected load of 880,000 kilo-volt-amperes. Among the electrical processes now in use in the United States, the following would be particularly adapted to this region: The production of alloy steels, such as ferrosilicon, ferromanganese, ferrophosphorus, and ferrochrome; the melting of nonferrous metals, such as copper, brass, and bronze; the production of zinc; the making of steel and malleable iron castings from scrap. At present the reduction of aluminum from alumina is already a thriving industry in this basin, and ferrosilicon is also being produced. In the prospective list should be mentioned here the rapidly growing use of the electric current for the heat treatment of steel, and in the precipitation of chemicals by the Cottrell process, which among other things can now be used for obtaining potash as a by-product in the manufacture of cement. And to these should be added those processes which now appear as certain of perfection in the near future, i. e., the electric smelting of iron ores into pig iron and the use of electric current in smelting copper sulphide ores.

The nonmetallic minerals of the Tennessee Basin offer also many possibilities for electrical power uses, as in the manufacture of abrasives, potash, phosphoric acid, and calcium carbide, which latter is now the source of acetylene, acetone, and acetic acid. In this connection attention is invited to the letter from Dr. T. P. Maynard appearing in Appendix F.

Great as would seem the possibilities for the application of hydroelectric power in electrochemical, electrometallurgical, and electrolytic processes, the fact remains that to date but little headway has been made in this direction in the Tennessee River Basin. Scarcely any of the processes now in use utilize local mineral products; the greatest industry of its kind in the basin, the production of aluminum, utilizes entirely raw materials brought from distant sources. On the other hand, many local raw materials capable of being reduced electrically, and including bauxite, are now being shipped to points outside of the basin for treatment or manufacture.

The information gathered to date shows that although electrical processes of the kind above referred to require fairly large amounts of power, nevertheless few such processes would warrant the construction of hydroelectric installations as part of their necessary plant and equipment. In the Tennessee Basin, to-day, the only electrochemical plant utilizing power from its own hydroelectric installation—through a subsidiary company—is the Aluminum Co. of America. The justification, in this instance, is found in the enormous amount of power required and the desire to be able to control voltage fluctuations within narrow limits, the latter being an important requirement in the reduction processes used. But in the majority of cases manufacturers prefer to buy power from the central stations of a public service corporation rather than venture out into the field of water-power development. The latter method would doubtless furnish them cheaper power, but would, on the other hand, greatly increase their capital costs and also their risks. Last, but not least, the manufacturer does not, under present laws, enjoy the right of eminent domain as does the public service corporation, and therefore can not hope to acquire lands and rights of way for hydroelectric purposes for the same price as paid by the latter.

What has been said concerning the purchase of electric power for electrochemical processes applies with even greater force to other lines of manufacture, because machinery in factories does not, as a rule, call for heavy electric loads or high-load factors, and few manufacturers, therefore, will care to build water-power plants for their own purposes. It would follow, therefore, that the many varieties of industries which logically seem to belong in the Tennessee basin are not likely to locate there unless a water-power development program is initiated that will insure ample purchasable power for new industries, and that will continue to develop additional power sources as fast as the demand for power grows. Thus far there has been no such definite program, and the developing of water power in this region has been to a large extent a matter of haphazard growth in which capital has had to take its chance. It is more than likely that the risks in some instances have been considerable, for the uncertainties in hydroelectric enterprises are often serious ones—uncertainties as to first cost; uncertainties as to legal obstacles; and uncertainties as to probable growth of the power market served—all of them vital and usually beyond definite anticipation.

There is much that the proposed survey could accomplish toward eliminating some of these uncertainties, or at any rate, reducing them to more definite proportions. For instance, accurate determinations of foundation conditions for dams at the more important proposed sites would eliminate such disastrous experiences as the one had at Hales Bar with seamy rock formations. Accurate determinations of available water supply through the systematic gauging of streams, surveys of reservoir sites, and storage studies, would eliminate errors in design due to having to guess at the stream flow—a common source of trouble in the past. A study of the sediment transported by the various streams of the basin would help to remove doubts as to the probable life of storage reservoirs, a question which is at present among the deferring influences that militate against power development in the Appalachian region. Finally, a logical program of power development for the entire basin, worked out so as to coordinate all future power production, not only with respect to market requirements, but also with respect to the economic utilization of water in a manner beneficial to navigation requirements and in reducing of flood crests, would enable the power producer, on the one hand, to follow a mapped-out course in which the principal risks have been removed, and would enable the mine operator and the manufacturer, on the other hand, to follow a program of industrial expansion in which the power and water transportation needs are adequately provided for and leave no room for doubt.

It is scarcely necessary to point out that the working out of such a comprehensive program calls for the most impartial consideration of the needs of a wide variety of interests, including those of the Government; moreover, these interests are distributed in portions of seven States covered by the drainage basin of the Tennessee. It would appear, therefore, that only a governmental agency through a survey of the kind here considered can adequately work out such a program.

EARTHQUAKES.

In regions of highly complex structural geology and at present subject to formative stresses and strains, as is the case in the eastern portion of the Tennessee River Basin, it is natural to expect frequent readjustments in the earth's crust. Such readjustments usually are in the nature of light earthquake shocks or vibrations. Because of the possible bearing that earthquakes may have on the future location and design of large hydraulic structures in this region an effort has been made to list all seismological disturbances in this portion of the United States of which any record could readily be found. The list, Table 40, though incomplete, serves to demonstrate that disturbances of this kind are very frequent there, but rarely of any marked violence. Only two violent shocks have occurred within a century, the so-called New Madrid earthquake of December 15, 1811, which caused much devastation in western Tennessee, and the so-called Charleston earthquake of August 31, 1886, which destroyed the city of Charleston, S. C. In both these instances severe shocks were felt in the Tennessee basin. In 1889, 1895, and 1913 severe shocks were felt in that region without, however, doing any damage.

It is unfortunate that no seismographs are located in or near this section. The nearest well-equipped stations are at Washington, D. C., New Orleans, La., and Mobile, Ala. It may be taken for granted, therefore, that practically nothing is known regarding the frequency and intensity of the minor seismological disturbances in the Tennessee region. Presumably they are much more frequent than the table would seem to indicate. On the other hand, it is reasonable to suppose that violent shocks, especially those accompanied by severe damage and loss of life, would be matters of common knowledge, and of this class of phenomena only two cases are on record.

The available evidence points to the conclusion that as compared with earthquakes in other sections of the United States where there are formative stresses in the earth's crust, the intensities and frequencies of earthquakes in the Tennessee River region offer nothing exceptional, and the inference naturally would be that little apprehension need be felt with regard to the stability of high dams or long conduits in this region, but that it will be wise, nevertheless, to make such structures proof, in so far as this can be done at reasonable cost, against unequal settlement of foundations, slight lateral movements, and light shocks.

There are localities in the Tennessee Basin where slips of mountain sides have occurred, in some cases involving much damage to railroad property. Such occurrences have been principally in shale formations and are attributable either to the presence of water-bearing strata which promoted slipping, or to artificial excavations, which caused unbalanced pressure.

A dozen or more well-defined fault planes extend through the eastern portion of the Tennessee Basin. No information is now available as to which of these faults are likely to be subject to further movement, and which have consolidated to a point where further movement need not be looked for. Displacement may now be going on at obscure faults concerning which little is known.

The subject in general is of such importance as to call for a certain amount of investigation in connection with the survey to be undertaken, including more in particular the accurate location and study of all important fault planes in localities where dams or other hydraulic structures are likely to be built.

TABLE 40.—*List of earthquakes in southern Appalachian region.*

Date.		Place where recorded.	Authority and description.
Year.	Day.		
1811	Dec 15.....	New Madrid, Mo.....	Severe; caused much damage and formation of Reelfoot Lake, in west Tennessee; described in U. S. Geological Survey Bulletin 494.
1812	Jan. 23.....	.....do.....	Light shock; described in U. S. Geological Survey Bulletin 494.
1812	Feb. 7.....	.....do.....	Do.

TABLE 40.—*List of earthquakes in southern Appalachian region—Continued.*

Date.		Place where recorded.	Authority and description.
Year.	Day.		
1872	Apr. 20.....	Memphis, Tenn.....	Slight shock reported by Weather Bureau at Memphis.
1873	May 3.....	.....do.....	Reported by Weather Bureau at Memphis; 2 severe shocks; wave north to south; no damage.
1875	Oct. 27.....	.....do.....	Do.
1877	July 14.....	.....do.....	3 shocks; vibration southwest to northeast; buildings rocked; no damage; reported by Weather Bureau at Memphis.
1878	Nov. 18.....	.....do.....	Heavy vibrations; swung pictures violently; no damage; reported by Weather Bureau, Memphis.
1880	July 13.....	.....do.....	Light shock reported by Weather Bureau, Memphis.
1881	Oct. 7.....	.....do.....	Severe shock reported by Weather Bureau, Memphis.
1883	Jan. 8.....	.....do.....	Light shock reported by Weather Bureau, Memphis.
1884	Nov. 29.....	.....do.....	Reported at Weather Bureau, Memphis; no damage.
1886	Aug. 31.....	Eastern United States, especially at Charleston, S. C.	Comprehensive report in Ninth Annual Report, U. S. Geological Survey, 1887-88; shock felt over eastern United States and as far north as Canada; destroyed Charleston, S. C.; much faulting and change of contour resulted; also recorded at Memphis Weather Bureau and other localities.
1888	Nov. 3.....	.....do.....	Shock reported by Weather Bureau, Memphis; direction, north-northwest to south-southeast; windows rattled.
1889	Jan. 5.....	.....do.....	Light shock reported by Memphis Weather Bureau.
1889	July 19.....	.....do.....	Severe shock; walls cracked; people in panic; direction, north-northeast to south-southwest; reported by Weather Bureau, Memphis.
1892	Jan. 14.....	Memphis, Tenn.....	2 shocks; shook buildings; no damage; reported by Memphis Weather Bureau.
1894	July 18.....	.....do.....	Light shock; wave south to north; no damage; reported by Memphis Weather Bureau.
1895	Oct. 3.....	.....do.....	Slight shock reported by Memphis Weather Bureau.
1895	Oct. 31, Nov. 1, 2.	Epicentrum at Charleston, Mo.	Area affected was 400,000 square miles; broke windows, cracked brick walls, etc.; described in Proceedings of the Indiana Academy of Sciences, No. 5, 1895; also reported at Memphis.
1901	Sept. 14.....	Memphis, Tenn.....	Slight shock recorded at Memphis Weather Bureau.
1903	Oct. 4.....	.....do.....	Do.
1905	Aug. 21.....	.....do.....	Do.
1908	Dec. 28.....	.....do.....	Quake reported by G. M. Garvey, 807 Adams Avenue, Memphis.
1911	Mar. 31.....	.....do.....	Slight shock recorded at Memphis Weather Bureau; direction, north to south.
1913	Mar. 28.....	Knoxville, Tenn.....	Described in Tennessee Geological Survey Resources, Volume IV, No. 1; also recorded by Weather Bureau, Knoxville; felt over area of 40 miles radius.
1913	Apr. 17.....	Epicentrum north of Ducktown, Tenn.	Described in Tennessee Geological Survey Resources, Volume IV, No. 1, and Bulletin, Seismological Society, page 191; shook houses; accompanied by loud roar.
1914	Mar. 5.....	Knoxville, Tenn.....	Slight shock reported by Weather Bureau, Knoxville, Tenn.
1914	Dec. 23.....	Summersville, S. C.....	Very faint shock; listed in Weather Bureau record.
1915	Jan. 14.....	Bristol, Tenn.....	Light shock; American Yearbook, 1915, and Weather Bureau record.
1915	Apr. 28.....	Tiptonville, Lake County.	Sharp shock; American Yearbook, 1915, and Weather Bureau record.
1915	Oct. 29.....	Asheville, N. C.....	Felt by persons walking; reported by Weather Bureau.
1915	Dec. 6.....	Tennessee, Kentucky, Illinois, and Missouri.	The Commercial-Appeal, Memphis, Tenn., Dec. 8, 1915.
1915	Dec. 7.....	Memphis, Tenn.....	Slight shock recorded at Memphis Weather Bureau.
1915	Dec. 13.....	Charleston, S. C.....	Weak shock reported to Weather Bureau.
1916	Feb. 21.....	Felt at many points in Alabama, Georgia, South Carolina, Virginia, and east Tennessee.	Slight shock reported by Weather Bureau, Knoxville, Tenn.; in other localities strong enough to be felt by nearly everyone.
1916	June 25.....	Summersville, S. C.....	Light shock; listed in Weather Bureau record.
1916	July 14.....	.....do.....	Do.
1916	Aug. 26.....	Western North Carolina.	Light to moderate; moved furniture; reported to Weather Bureau.
1916	Sept. 24.....	Summersville, S. C.....	Very light; listed in Weather Bureau record.
1916	Oct. 18.....	Alabama, Georgia, Mississippi, South Carolina, and east Tennessee.	Slight shock reported by Weather Bureau, Knoxville, Tenn.
1917	Mar. 2 and 4.....	Knoxville, Tenn.....	Do.

TABLE 40.—*List of earthquakes in southern Appalachian region—Continued.*

Date.		Place where recorded.	Authority and description.
Year.	Day.		
1917	Mar. 25, 26, 27..	Jefferson County, Tenn.	Light to moderate; shock of Mar. 27 felt by nearly everyone and moved furniture at Jefferson City; listed in Weather Bureau record.
1917	April 9.....	Obion County, west Tennessee, and Evansville, Miss.	Moderate; listed in Weather Bureau record.
1917	April 11.....	Central South Carolina..	Light; listed in Weather Bureau record.
1917	June 9.....	Henry County, west Tennessee.	Faint; listed in Weather Bureau record.
1917	June 21.....	East Tennessee.....	Light to moderate; American Year Book, 1918.
1918	Jan. 17.....	Center at Smithwood, Tenn. (north of Knoxville).	Reported by Weather Bureau, Knoxville, Tenn.; rattled dishes, swung pictures, etc.
1918	June 22.....	East Tennessee.....	Light to moderate; felt by nearly everyone; listed in Weather Bureau record.
1918	Oct. 4.....	Memphis, Tenn.....	Recorded at Memphis Weather Bureau; windows rattled and objects on tables moved; vibration east to west.
1918	Oct. 15-16.....	Memphis, Tenn., and west Tennessee.	Recorded at Memphis Weather Bureau; rattled windows; wave north to south; low rumblings heard.
1919	May 23.....	New Madrid, Mo.....	Very light; American Year Book, 1919.
1919	May 24.....	do.....	Do.
1919	May 26.....	do.....	Felt over area of 10,000 to 15,000 square miles; American Year Book, 1919.
1919	May 28.....	Tiptonville, Tenn.....	Listed in Weather Bureau record.
1920	Apr. 7.....	Springville, Henry County, Tenn.	Light; listed in Weather Bureau record.

GERARD H. MATTHES,
Assistant Engineer.

APPENDIX B.

[Report of Prof. J. A. Switzer.]

THE WATER POWER OF THE TENNESSEE RIVER BASIN.

General.—Owing to the very heavy rainfall peculiar to the portion of the Southern Appalachian region where lie the headwaters of most of the streams within the Tennessee River Basin (a mean annual precipitation of about 60 inches) and to the relatively steep gradients characterizing these streams, the water-power resources of the basin are exceedingly important. The fact that this region is highly mineralized, and hence is a source of a great variety of the raw products required in the chemical and manufacturing industries, enhances the intrinsic value of these water-power resources.

The present development of water power totals but a small fraction of the potential power of the region. Unquestionably, there is an immediate economic demand for the utilization of a much larger proportion, and ultimately all that can possibly be developed will be required.

The value of water power, from a purely investment point of view, is largely determined by the competitive cost of steam power. The cost of steam power is a function of the cost of coal, and it is a significant fact that since 1914 the cost of bituminous coal has advanced about 175 per cent. Although the general recession of prices which has now set in, following the war, will be extended to coal, it seems certain that the pre-war price will not again be reached, and that the definite upward trend of the cost of coal clearly seen before the war will never be checked.

Far above the investment point of view, however, lies the national point of view; and the broader outlook which is here afforded shows the development of water power to be vested with a permanent value above and beyond the immediate return to the investor.

For this reason it is a legitimate and an important function of the Federal Government to encourage and to stimulate the development of water power. In the case of the undeveloped water powers of the Tennessee River Basin, lack of definite information concerning the many possible power sites has proven to be a very real barrier to

their utilization, and the survey, authorized by Congress, by removing this barrier, will constitute an important national service.

The present development of water power.—The only hydroelectric plants that were in operation within the Tennessee River Basin 10 years ago were the three small stations of the North Carolina Electrical Power Co., located on the French Broad River just below Asheville, N. C. These are low-head plants, operating without pondage, and having a combined installed capacity of 7,500 horsepower. The company operates a steam auxiliary plant of 3,500 horsepower capacity.

Except for these plants there were no water-power developments within the basin in 1910 of more than a few hundred horsepower capacity. A special water-power census, taken in 1908 by the Census Bureau, found 1,691 water wheels installed within the Tennessee River Basin in the State of Tennessee, having a combined reputed capacity of 85,548 horsepower, or an average of 50 horsepower per plant.

In the year 1911 the plant of the Watauga Power Co. (now owned by the Utilities Improvement Co.) was completed. This 3,200 horsepower plant is located on the Watauga River, 18 miles south of Bristol, Tenn., to which city the power is transmitted. An auxiliary steam plant is located in Bristol.

The largest hydroelectric service company in the Tennessee River Basin is the Tennessee Power Co. Their first water-power plant was completed in 1912. This plant is located at Parkville, Tenn., on the Ocoee River. A dam 100 feet high was built, which impounds 100,000 acre-feet of stored water. About 31,000 acre-feet of this is available for power. The installed capacity of the plant is 25,000 horsepower. Back of the plant is a drainage area of 607 square miles. In 1914 a second plant on the Ocoee River was built. This plant, located 12 miles above the other, consists of a timber crib dam 40 feet high, a timber flume measuring 10 by 14 feet and 5 miles long, which conveys the water to the power house, and the power house itself. Two 10,000 horsepower turbines are installed. The catchment area measures 515 square miles, and the plant operates without pondage. The head on the turbines is 260 feet. Higher on the Ocoee River the company holds rights to other power sites, which when developed will create considerable storage, and from this the lower plants will benefit.

At Great Falls, on the Caney Fork (a tributary of the Cumberland River), the Tennessee Power Co. has built a third water-power plant to develop 12,000 horsepower. In addition to these three plants the company operates, under lease, the plant of the Chattanooga & Tennessee River Power Co. This plant is located on the Tennessee River at Hales Bar, 33 miles (by river) below Chattanooga, and has an installed capacity of 62,000 horsepower. The company has steam auxiliary plants located at Chattanooga, Parkville, and Nashville, with a total generating capacity of 44,000 horsepower, and it has an operating agreement with the Knoxville Railway & Light Co. whereby the 9,000 horsepower plant of that concern may be called upon at any time for power. The company maintains about 1,000 miles of transmission line, connecting with Knoxville, Maryville, Mascot, Nashville, Chattanooga, and numerous smaller towns.

The dam at Hales Bar was built at the instance of the Federal Government and primarily for the purpose of improving navigation. The dam is 40 feet high, and it provides slack-water navigation through the "mountain section" of the Tennessee River, a section which had been a serious bar to any navigation whatever. The river here passes through the barrier of the Cumberland Mountains, and between Hales Bar and Chattanooga there was a series of shoals and rapids. The dam was built under a 99-year lease from the Government to the Chattanooga & Tennessee River Power Co., and only the lock through the dam was built at public cost. Construction was begun in 1905 and the plant was nearly enough completed to begin generating power in 1913. Enormous difficulty was met in getting suitable foundation for the dam and the power house, which forms a part of the dam itself. The length of the structure is 2,500 feet. The spillway section is 1,200 feet long and the power house 800. The lock is 60 feet wide and 312 feet long between quoins. The downstream gates are 58 feet high, and the lock is said to be the highest single-lift lock in the world.

The last public utility water-power plant to be enumerated is that of the Tennessee Eastern Electric Co. This plant is located on the Nolichucky River, 9 miles south of Greeneville. The dam is 39 feet high, but was built with foundation suitable for a height of 70 feet, to which height it will be raised later. The plant was put in operation in 1913 with an installed capacity of 3,600 horsepower. The 70-foot dam will make a pool 9 miles long and it will warrant an installation of 16,000 horsepower. The power is transmitted to Greeneville and to Johnson City, where 1,800 horsepower of steam auxiliary power is available.

The largest and most important water-power development within the basin is that of the Aluminum Co. of America. This concern has purchased all of the water rights

on the Little Tennessee River from a point about 10 miles west of the Tennessee-North Carolina State line to its source, together with all of its tributaries in North Carolina—the Cheoah, the Nantahala, and the Tuckasegee Rivers. The complete project for the development of this power contemplates the building of about nine dams, the storage of immense bodies of water, and the development of approximately 400,000 horsepower. The first dam was completed in 1918. This dam, across the Little Tennessee at the mouth of the Cheoah River, is 200 feet high, being the highest overfall dam in the world. The present power equipment consists of three units of 24,000 horsepower each. A fourth unit will be installed when some of the upper storage is developed. The Aluminum Co. of America is not proposing to develop this power to sell, but for the operation of its great manufacturing plant at Alcoa, Tenn. Their present supply of power from the Little Tennessee River is supplemented by that of a 10,000 horsepower steam plant at the Alcoa works and by the purchase of approximately 25,000 horsepower from the Tennessee Power Co.

THE UNDEVELOPED WATER POWER.

The undeveloped water power in the Tennessee River Basin capable of ultimate profitable utilization undoubtedly exceeds 1,000,000 horsepower. This figure excludes projected developments of the Tennessee Power Co. and of the Aluminum Co. of America, already referred to.

Preliminary estimates of the quantity of power which may be developed at any given site are necessarily only approximate. Until the data which the authorized survey of the Tennessee River Basin will accumulate is available for study these estimates can be regarded only as more or less scientific guesses. Such estimates, when made, are based upon the known stream-flow data and upon such knowledge of river profiles and the topography of the river basins as may have been secured.

In 1907 Congress, in connection with the agricultural appropriation bill, called upon the Secretary of Agriculture to "examine, survey, and ascertain the natural conditions," etc., of the rivers of the White Mountains and the Southern Appalachian Mountains "in the interest of agriculture, water power, and navigation." The sum of money allocated to this large task is inadequate. The Department of Agriculture turned the assignment over to the United States Geological Survey. Such work as the Geological Survey was able to do with the allowable expenditure is reported in Forest Service Circular 144, issued on March 20, 1908. The circular contains very valuable information, yet its authors would doubtless admit that as a "survey" the study would necessarily be classified as "an armchair survey." No special field work is back of the report.

The writer of the present paper has made himself thoroughly familiar with circular 144 and with all of the sources of information which were available to its authors.

During the years which have intervened since the issue of the circular he has personally familiarized himself to a considerable extent with nearly all of the rivers within the Tennessee River Basin and has posted himself upon such investigations as have been made by others within this territory. These investigations, aside from those which have led to the water-power developments already described, are exceedingly scant, and it can not be claimed that the sum total of knowledge of the undeveloped water powers of the Tennessee River Basin is even to-day more than fragmentary. A private water-power corporation before undertaking any single development of importance will spend more money upon its study than has been spent on the total unexploited water-power resources of the entire basin.

For the purpose of making preliminary estimates of the water power of this region, it is most fortunate that topographic sheets have been issued by the United States Geological Survey covering almost the entire area of the basin. By mounting these sheets together one gets a large topographic map by means of which the rivers almost in their entirety may be studied. By such a study one can select promising power sites, estimate possible heights of dams, draw the approximate flow lines of such reservoirs as these dams would create, and determine with very good accuracy the drainage areas tributary to each power site. By the aid of this map it is thus very easy to build dams—on paper. One can then visit the actual sites, cross section the river and valley, and make such examination of the geological formation as circumstances permit. The writer has done this for most of the power sites described in this report. In selecting tentative power sites for such a study and in assigning to dams possible heights to which they could practically be built, one gives careful consideration to existing railroad locations, bridges, towns, etc. A map covering the portion of the Tennessee River Basin lying above Chattanooga has been prepared and is submitted as part of this report. The results of the study of the larger undeveloped

water powers is summarized in a table herewith. The listed power sites are by no means all that exist, and the extended survey when made will unquestionably show some of them to be less attractive, commercially, than others. It is to be expected that thorough geological exploration of the various dam sites will reveal some of them as unsuitable for dams of the suggested height. Because of the agricultural value of the lands to be flooded by certain of the dams, their building will necessarily be deferred until the increasing relative value of power overtakes the cost of these lands.

POSSIBLE POWER DEVELOPMENTS.

Tennessee River from Chattanooga to Riverton.—The Hales Bar Dam develops all the power available from Hales Bar to Chattanooga. From Hales Bar down to Browns Island, a distance of 140 miles, the fall is about 56 feet, or an average of only 0.4 foot per mile. There are probably no waterpower possibilities in this stretch. In the Muscle Shoals section a fall of about 120 feet occurs within a distance of 35 miles. The Muscle Shoals power development now under construction by the Government will ultimately utilize all the power which this fall will generate.

From Muscle Shoals to Riverton the fall is approximately 38 feet in a distance of 30 miles. Of this amount 24.5 feet of fall occurs within the 8.7 miles lying between the head of Colbert Shoals and the town of Riverton. It is extremely doubtful whether this section of the river can be made to yield any appreciable quantity of water power.

TENNESSEE RIVER FROM ITS BEGINNING TO CHATTANOOGA.

The Tennessee River is formed by the junction of the French Broad and Holston Rivers, about 5 miles above Knoxville. Above the city and just below the confluence of these streams is a possible site for a dam 40 feet high. This dam is designated in the accompanying table and on the map¹ as Dam No. 7. The dam would require approximately 51,000 cubic yards of concrete. It would create a pool extending up the Holston River for 6 miles and up the French Broad for 16 miles and would flood about 15,000 acres of land. The tributary drainage area is 8,990 square miles.

Twelve miles below Knoxville at the Little River Shoals is a site for a 20-foot dam which would back water to the toe of Dam No. 7. This is designated as Dam No. 29 in the accompanying table. The site was selected by the Corps of Engineers and was described as Lock and Dam 11 in the report of Gen. W. H. Bixby of December 28, 1911.

Ninety miles below Knoxville, at the Caney Creek Shoals, is a site for another 20-foot dam listed as No. 30. This site is described in the above report as Lock and Dam No. 6. The drainage area above Dam No. 29 is 9,560 square miles and that above Dam No. 30 is 17,070 square miles.

In the entire stretch of the river between Knoxville and Chattanooga, 188 miles long, there appear to be no other favorable power sites.

THE CLINCH RIVER AND ITS TRIBUTARIES.

The tributaries of the Clinch River are the Powell and the Emory. A tributary of the Emory River is the Obed River. Dam No. 30, across the Tennessee River, would back water up the Clinch River nearly to the mouth of the Emory River. Here on the Clinch River there are two dam sites. Dam No. 4 would be located below the mouth of the Emory, and would be limited in height to 45 feet by the location of the city of Harriman. The tributary drainage area is 4,420 square miles. The dam would require approximately 62,000 cubic yards of concrete. The alternative dam, No. 21, located above the mouth of the Emory River, could be built to a height of 85 feet, this limit being fixed by a railroad location. It would create slack water nearly to the town of Clinton, and would have back of it a drainage area of 3,550 square miles. The map shows the approximate flow line.

The next power site, Dam No. 3, located 5 miles east of Coal Creek, would permit of a dam 175 feet high. Such a dam would back water up the Clinch River for a distance of some 42 miles to the Southern Railway bridge at Clinch and up the Powell River a distance from its confluence with the Clinch River of about 35 miles, to the Southern Railway crossing at Ore Bed. The dam would require for its construction about 330,000 cubic yards of concrete. It would create enormous storage, flooding land of but little value. Taken in conjunction with the dams higher up on the Clinch and the Powell, the run-off at Dam No. 3 would be 100 per cent regulated.

¹ All dams referred to by number are shown in Chart VI.

Just above the station of Clinch, on the Clinch River, is an excellent site, shown on the map as Dam No. 2. Its height could be 160 feet, this limit being determined by the location of the town of Clinchport. The dam would require 298,000 cubic yards of concrete. The drainage area back of it is 1,548 square miles.

Above Clinchport the river valley is occupied for a distance of about 60 miles by a railroad. The fall within this reach of the river is approximately 260 feet.

The railroad leaves the river at a point near Cleveland, Va., and just above this point is a site for a 200-foot dam (No. 26). This dam would make a pool of 1,600 acres and would utilize the run-off from an area of 540 square miles. Above this reservoir site the valley is again occupied by a railroad.

The Powell River.—Just above Ore Bed, less than a mile above slack water from Dam No. 3, is located Dam No. 1. Its height is limited by no consideration other than that of the topography of the site, and the economic value of the power it would yield. While a dam over 200 feet high could be built without requiring an inordinate quantity of concrete, the drainage area which is tributary, namely, 700 square miles, would probably not warrant very great height; and the figure here adopted is 180 feet. A dam of this height would require about 274,000 cubic yards of concrete.

Headwater from Dam No. 1 would terminate near Jonesville, Va. Here is a site for a 100-foot dam which would flood an area of 2,900 acres; but since the drainage area is but 313 square miles it is questionable whether the run-off would justify the building of the dam. The dam is listed as No. 27.

THE EMORY AND OBED RIVERS.

Dam No. 4, 45 feet high, across the Clinch River below the mouth of the Emory, would back water to Harriman, on the Emory. Just above the mouth of the Emory is a site, No. 31, where a 43-foot dam would accomplish the same result. This dam would utilize the run-off from an area of 870 square miles and would create a pool of 1,500 acres.

Above Harriman, existing railroad locations along the Emory River prevent further power development.

On the Obed River, just above its confluence with the Emory, a dam 190 feet high could be built; and a penstock leading off down the Emory River could make a net head of 250 feet available at the power house. The dam would flood 1,540 acres, and would utilize the run-off from 524 square miles. Above this dam, a second dam 100 feet high could be built. But such a dam, with a drainage area of only 350 square miles behind it and making a pool covering but 650 acres, would not be justified.

THE HOLSTON RIVER AND TRIBUTARIES.

At a point 7 miles east of Mascot is located a site for a dam (No. 6) the height of which is fixed at 90 feet by the railroad crossing near the station of Holston. The tributary drainage area, 3,656 square miles, would make this an attractive site if the geological formation proves suitable.

Dam No. 5 is located just above Holston. This dam is limited to a height of 110 feet by the railroad bridge at Austin's Mills. The dam would require 151,000 cubic yards of concrete—slightly less than the quantity which went into the Parksville dam, 100 feet high, of the Tennessee Power Co. The drainage area back of Dam No. 5, 3,392 square miles, is approximately five and one-half times as great as that tributary to the Parksville plant.

Between Austin's Mill and Kingsport (an airline distance of about 26 miles) the fall of the river is approximately 60 feet. This reach would yield good power, but the Southern Railway tracks close by follow the river.

At Kingsport the river divides into the North Fork and the South Fork.

For some 25 miles above Kingsport the railroad parallels the North Fork to Mendota, precluding power development within this reach. Close to Mendota is a site, No. 24, for a 150-foot dam, which would flood 8,320 acres of land and would have back of it 475 square miles.

On the South Fork of the Holston, 10 miles southeast of Kingsport, is located a site where a 160-foot dam might be built. This dam would back water up the South Fork to Bluff City and up the Watauga to the railroad crossing at the town of Watauga. The drainage area is 1,800 square miles, and some 12,000 acres of land would be flooded.

Ten miles above Bluff City is a site for a 200-foot dam, No. 25. This dam would flood 8,200 acres and would use the run-off from 600 square miles.

A tributary of the South Fork is Middle Fork. A dam 100 feet high could be built without flooding the town of Chilhowie; but the small drainage area, 1,212 square miles, would hardly justify such a dam.

On the Watauga River, a tributary of the South Fork, a 90-foot dam could be built just above the town of Watauga, although it would involve the relocation of about 3 miles of railroad. The drainage area here is 683 square miles, and the dam would flood 1,600 acres, backing water almost to the city of Elizabethton. This is shown as Dam No. 34.

Four miles east of Elizabethton is located the plant of the Watauga Power Co., above which the drainage area is 408 square miles. Because of the railway location following the river upward from this point none but small power developments are possible for many miles. In Watauga County, N. C., at a point where the area drained is 150 square miles, a 500-foot development could be made. Such a plant, utilizing the mean minimum monthly flow of the six high-water months and operating at 50 per cent load factor, would have an installed capacity of possibly 15,000 horsepower. This development is shown on the accompanying map, and is designated as Dam No. 35. A dam 100 feet high would flood only 260 acres. If justified, a much higher dam could be built.

A tributary of the Watauga River, the Doe River, entering it at Elizabethton, has a drainage area of 140 square miles. This stream would yield some excellent power, except that a railroad took possession first.

FRENCH BROAD RIVER AND TRIBUTARIES.

At the mouth of Boyd Creek, just above the backwater from Dam No. 7, is the site of Dam No. 12. The height is limited to 45 feet because of the location of the town of Sevierville, on the Little Pigeon River. The dam would require but 50,000 cubic yards of concrete for its construction. Back of it the drainage area is 4,983 square miles. The pool would cover 12,000 acres.

A mile below Dandridge is site No. 11. A 75-foot dam here would back water under the railroad bridge at Leadvale, up the French Broad River above the mouth of the Big Pigeon River nearly to Newport, and a short distance up the Nolichucky River, which flows into the French Broad at Leadvale. The dam would contain about 150,000 cubic yards of concrete and would overflow 9,000 acres of land.

From Leadvale to Asheville, N. C., a distance of 75 miles, the fall of the river is 1,020 feet. For the entire distance, however, the Southern Railway follows the river closely, so that only small developments are feasible.

Above Asheville, about 3 miles above the mouth of the Swannanoa River, a 100-foot dam (No. 28) would impound a large body of water, making a lake over 20 miles long, and covering almost 10,000 acres. The drainage area is 650 square miles.

The Big Pigeon River is an exceedingly important power stream. From Canton, N. C., to Bluffton, Tenn., the river drops 1,400 feet. At Waterville, 5½ miles above Bluffton, the drainage area is 536 square miles. A company has recently been formed to develop the entire power of this river and tributaries. Detailed plans have been worked out, and the plans provide for a total installed generating capacity of 179,000 horsepower. This figure includes the power from five dams. Two other plants are comprised in the complete project, and these will bring the total capacity to approximately 200,000 horsepower.

On the Nolichucky River below the plant of the Tennessee Eastern Electric Co. there are two power sites, Nos. 9 and 10. At site No. 10 a 70-foot dam could be built requiring 69,000 cubic yards of concrete, and at No. 9 a 100-foot dam calling for 110,000 cubic yards. Both are favorable power sites, but the building of Dam No. 10 would interfere with a projected railway extension from Bulls Gap to Newport.

The dam of the Tennessee Eastern Electric Co., when built to the projected height of 70 feet, will back water nearly to Embreeville. At Erwin a 70-foot dam (No. 8) requiring only 59,000 cubic yards of concrete, can be built, which with a penstock leading down to Erwin will make available a head of 130 feet. The river at Erwin drains an area of 780 square miles.

From Erwin up almost to the source of the river (here called the North Toe River) a railroad occupies the river valley, to the exclusion of any but small power developments.

The Little Pigeon River has a drainage area at Sevierville of only 346 square miles. The location of the town of Sevierville precludes any power development except near the headwaters. There is one site above Sevierville where a high-head plant could develop approximately 400 horsepower.

THE LITTLE RIVER.

The total drainage area of the Little River is 350 square miles. Just above Rockford there is a possible site for a dam approximately 50 feet high. Such a dam, however, would flood a disproportionately large area of high priced land, and the low

head, small draw-down, and limited drainage area would seem to disqualify the site from serious consideration. At Walland, where the river breaks through the Chilhowee Mountains, a good power site is made unavailable by the location of a railroad and of the town of Walland. East of Tuckaluchee Cove the river is precipitous and a 300-foot head could be concentrated by a relatively short pipe line; but there is no site for storage. With the flow from an area of 60 square miles, a 1,000 horsepower development would possibly be justified.

THE LITTLE TENNESSEE RIVER AND TRIBUTARIES.

Three miles northwest of the railroad crossing at McGhee. Dam No. 15 could be built to a height of 30 feet. The dam would require but 36,000 cubic yards of concrete. While but little useful storage would be available at the dam site, the plant would profit by the large degree of stream regulation to be effected by the developments of the Aluminum Co. of America higher up. This is the only power site on the Little Tennessee now owned by the aluminum company.

The two tributaries of the Little Tennessee not controlled by the aluminum company are Abrams Creek and the Tellico River. The available drainage area of Abrams Creek is only 60 square miles. Yet a 65-foot dam calling for but 28,000 cubic yards of concrete will give at least 80 per cent of stream regulation and a flume line 10 miles long will yield a net head of 820 feet. Doubtless this power would have been developed before but for the lack of adequate transportation to the dam site.

The location of the town of Tellico Plains, at the head of the valley called Tellico Plains, precludes the development of a power site the utilization of which would convert the plains into a wonderfully fine reservoir. Ascending from the town of Tellico Plains, the river enters the Unaka Mountain range, and rises rapidly from an elevation of less than 900 feet above sea level to 3,500 feet at its source. A standard-gauge logging railroad parallels the stream, and while its location there prevents the building of a storage dam it would facilitate the quick development of a meritorious flume proposition. Such a proposition has received careful engineering study, the result of which shows a feasible development consisting of two plants. The diversion dam for the upper plant would be served by a drainage area of 85 square miles. From the dam a flume 23,000 feet in length would render available a net head of 175 feet. Immediately below the upper power house, a second dam would divert the water from a drainage area increased to 106 square miles into a second flume, which in a length of 7,400 feet would yield a net fall of 70 feet. Basing power calculations on a stream flow equal to one-half the mean annual rate of run-off and 50 per cent load factor, the power yield of the two plants would be 5,500 horsepower.

THE HIWASSEE RIVER.

The Hiwassee River is a very important power stream, of which the Ocoee is a tributary. Below the mouth of the Ocoee there are two power sites, and above it four. Site No. 18 is situated 4 miles above the mouth of the Hiwassee River itself and No. 17, 16 miles higher, is located near Charleston, Tenn. Dam No. 18 is limited in height to 25 feet by reason of the Southern Railway crossing at Charleston. The dam would require but 20,000 cubic yards of concrete, and like Dams Nos. 4 and 21 on the Clinch River, No. 7 on the Tennessee, and Nos. 11 and 12 on the French Broad, and No. 15 on the Little Tennessee would doubtless be designed as a movable crest dam. The drainage area is 2,700 square miles.

Dam No. 17 is limited in height to 45 feet by the location of the Louisville & Nashville Railroad as it crosses the Hiwassee River below the mouth of the Ocoee. Water would be backed up under the bridge, and to a considerable distance beyond it, on both the Hiwassee itself and the Ocoee. The head of slack water on the Ocoee would in fact be located only about 2 miles below the Parkville Dam. The drainage area at Dam No. 17 is 2,205 square miles.

Dams No. 19 and No. 20, on the upper Hiwassee, cover the section of the river from the Tennessee-North Carolina State line to Murphy, N. C. Together they constitute the project of the Hiwassee Power Co. This project was fully reported upon for the company by Charles O. Lenz, of New York, in 1914. The holdings and rights of this company are in conflict with those claimed by another concern, the Carolina-Tennessee Power Co., and the matter is at present in litigation between them. The drainage area at site No. 20 is 1,050 square miles and at No. 19, 950 square miles. Dam No. 20 is 110 feet high and Dam No. 19, 143 feet. Dam No. 19 is located at the head of slack water from Dam No. 20, and will itself back water nearly to Murphy, N. C. These are both attractive power propositions and but for the legal complications due to rival claims would doubtless have been developed long since.

More attractive than either of these, however, is a possible project located just below Dam No. 20. The Louisville & Nashville Railroad from Knoxville to Atlanta enters the gorge of the Hiwassee River near Wetmore, at the point where the river emerges from the Unaka Mountains, here the principal range of the Appalachians. For a distance of nearly 16 miles it clings to the water's edge, reaching at Appalachia Station an elevation of about 1,200 feet. Here the railroad begins to climb away from the river's edge, and after making a loop, gains the plateau and turns sharply away from the river. A short distance above Appalachia Station there is a favorable site for a 50-foot dam, No. 22, which would back water to the toe of Dam No. 20. From this dam a pipe line would lead off down the river. With a length of 3 miles a net head of 190 feet would accrue, while with a length of 7 miles a head of 360 feet net would be available. With a drainage area of 1,080 square miles the mean annual run-off is approximately 2,800 second-feet.

Above Murphy there is a site for a dam (No. 31) 80 feet high, which would flood 3,320 acres and have back of it a drainage area of 400 square miles.

THE CUMBERLAND PLATEAU STREAMS.

Most of the streams rising on the Cumberland Plateau find their way into the Cumberland River.

Along the eastern escarpment of the plateau there is a series of small streams, however, which empty into the Tennessee River. None of them are important as a power stream; yet because of the heavy gradients characterizing them, they may some day be utilized for small, high head developments. Among them are Fall Creek, Piney, Richland, Bridge, Rock, Soddy, Suck, and North Chickamauga Creeks.

South Chickamauga Creek is a stream of considerable volume, perhaps, but of such light gradient as to have little value as a power stream. The only possible dam site is occupied by a railroad.

Sequatchie River.—The Sequatchie River drains an area of 610 square miles; but, like South Chickamauga Creek, the gradient is light, and the stream does not lend itself to power development. At a point $5\frac{1}{2}$ miles south of Pikeville, a dam 40 feet high could be built, or at a point a mile north of the city a 60-foot dam; but the drainage area of 130 square miles is too small to warrant either dam. The Little Sequatchie, a tributary of the Sequatchie, has a drainage area of about 100 square miles. The gradient is much steeper than that of the larger river, and there appears to be one site at which two or three hundred horsepower could be developed.

ELK RIVER.

Neither the Elk nor the Duck River has been thoroughly prospected for water power. At Winchester there is a 200-horsepower plant on the Elk River. The drainage area here is 430 square miles. At Fayetteville the drainage area is 800 square miles. What power sites there are I do not know.

DUCK RIVER.

At Shelbyville the drainage area is 450 square miles. At Columbia 1,180 square miles. Here there is a small hydroelectric plant. At Centerville the drainage area is 2,080 square miles. Here is located what appears to be a good site for a 60-foot dam. If the minimum flow for the six high-water months is 1,000 second-feet, a development of possibly 1,100 horsepower could be made. At Hurricane Mills, below the mouth of the Buffalo River, there is a site for a dam 50 to 60 feet high, and as the area here is 3,450 square miles a development of 2,000 horsepower might be had. The Buffalo River contributes to the Duck the run-off from 735 square miles. On the Buffalo River, at a point in the northern end of Wayne County, back of which the drainage area is 415 square miles, there appears to be a site for a dam 50 or 60 feet high.

CALCULATION OF POWER AT THESE SITES.

In the accompanying table the significant data covering run-off at each site is presented as accurately as a study of existing stream measurements will yield this information. Upon the basis of this data and the heads which the various projects will afford, the plausible values of horsepower are calculated. The power yield of a water-power project should be stated in horsepower-hours rather than in horsepower; but to do so one must plot mass curves and indeed have at his command all of the information which the projected survey will accumulate.

The larger undeveloped water powers of the Tennessee River basin.

Dam No.	Name of river.	Steam flow.					Height of dam (feet).	Mean head of turbines (feet).	Area of pool (acres).	Storage capacity (thous. and of acre-feet).	Assumed draw-down (thous. and of acre-feet, upper storage not considered).	Storage discharge in cubic feet per second for 6 months per year, 24 hours per day.			Economic plant capacity based on 50 per cent load factor and 80 per cent efficiency.	
		Average run-off for year (cubic feet per second per square mile).	Mean flow for year (cubic feet per second).	Mean monthly minimum flow for 6 high-water months (cubic feet per second per square mile).	Mean monthly minimum flow for 6 high-water months (cubic feet per second).	Mean monthly minimum flow for 6 high-water months (cubic feet per second).						From reservoir at power site.	From upper storage.	Total at dam.	Horse-power, not utilizing upper storage.	Horse-power, utilizing upper storage.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Powell.....	700	2.00	1,400	1.00	700	180	170	31,100	1,870	475	1,310	164	1,474	31,000	33,000
27	do.....	313	2.00	1,626	1.00	313	100	90	2,900	97	60	164	22	164	5,000	5,000
14	Clinch.....	4,420	1.95	8,640	1.00	4,420	45	40	10,900	163	8	22	6,018	6,040	32,000	48,000
1	do.....	3,551	2.00	7,102	1.00	3,551	85	75	24,140	681	200	550	5,813	6,263	49,000	80,000
2	do.....	1,548	2.00	3,096	1.00	1,548	160	150	27,400	1,460	800	2,200	2,19	2,419	43,000	44,000
3	do.....	2,883	2.00	5,766	1.00	2,883	175	165	66,000	2,100	700	1,920	3,893	5,813	130,000	160,000
26	do.....	540	2.00	1,080	1.00	540	200	200	1,600	107	80	219	205	227	18,000	18,000
132	Emory.....	870	1.90	1,655	.95	826	43	40	1,500	21	75	205	205	205	7,000	8,000
23	Obed.....	525	1.80	1,045	.95	500	90	200	1,540	97	75	205	205	205	41,000	41,000
30	Tennessee.....	17,030	2.00	34,060	1.20	20,500	20	18	17,900	240	100	272	6,600	6,600	26,000	58,000
29	do.....	9,560	2.00	19,120	1.20	11,500	20	18	17,900	240	100	272	6,600	6,600	26,000	36,000
7	do.....	8,990	2.00	17,980	1.20	10,800	40	37	14,300	215	80	219	2,219	2,438	45,000	55,000
12	French Broad.....	4,983	2.20	10,950	1.30	6,480	45	40	14,300	270	80	219	2,000	2,219	45,000	55,000
11	do.....	4,455	2.20	9,800	1.30	5,800	75	70	10,800	295	150	410	884	1,076	20,000	20,000
28	do.....	650	2.50	1,625	1.60	1,040	100	85	9,850	200	70	192	884	1,076	20,000	20,000
9	Nolichucky.....	1,752	2.10	3,680	1.20	2,100	70	60	8,800	326	250	684	± 200	± 200	35,000	35,000
10	do.....	1,342	2.10	2,820	1.20	1,610	100	90	8,800	326	250	684	± 200	± 200	35,000	35,000
13	do.....	780	2.10	1,620	1.30	1,015	70	70	8,350	5	5	14	14	14	18,000	18,000
18	Pigeon.....	4475	2.70	1,280	1.50	713	250	230	1,540	128	100	274	500	500	170,000	170,000
5	Holston.....	3,392	2.00	6,784	1.10	3,740	110	100	14,500	508	200	548	3,051	3,600	75,000	85,000
24	do.....	3,656	2.00	7,312	1.10	4,010	90	80	10,750	326	160	440	3,000	4,040	70,000	82,000
6	North Fork of Holston.....	475	2.00	950	1.10	522	150	140	8,320	416	275	755	755	755	16,000	16,000
23	South Fork of Holston.....	1,800	2.20	3,960	1.30	2,360	180	150	11,000	640	420	1,150	1,146	2,296	90,000	110,000
35	do.....	1,600	2.20	3,200	1.30	2,080	200	180	8,200	645	400	1,080	1,146	1,46	14,000	22,000
34	Watuga.....	600	2.40	1,440	1.50	900	90	85	1,600	48	15	41	25	66	12,000	13,000

• Actual projected installation.

• Projects involve two developments with flume lines.

1 Project 21 is alternative with 4 and 32.

The larger undeveloped water powers of the Tennessee River basin—Continued.

Dam No.	Name of river.	Steam flow.					Height of dam (feet).	Mean head on turbines (feet).	Area of pool (acres).	Storage capacity (thous. acre-feet).	Assumed draw-down (thous. acre-feet, not considered).	Storage discharge in cubic feet per second for 6 months per year, 24 hours per day.				Economic plant capacity based on 80 per cent load factor and 80 per cent efficiency.	
		Drainage area (square miles).	Average run-off for year (cubic feet per second per square mile).	Mean flow for year (cubic feet per second).	Mean monthly minimum flow for 6 high-water months (cubic feet per second per square mile).	Mean monthly minimum flow for 6 high-water months (cubic feet per second).						From reservoir at power site.	From upper storage.	Total at dam.	Horse power, not utilizing upper storage.	Horse power, utilizing upper storage.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
35	Watnaga.....	150	2.40	360	1.50	225	100	500	260	9	9	25	.....	25	17,000	17,000
15	Little Tennessee.....	2,456	2.60	6,400	1.30	3,190	30	27	6,880	69	30	82	±2,000	2,082	16,000	22,000	
14	Abram Creek.....	2,339	2.70	105	1.50	58	65	370	1,470	33	33	90	.....	90	17,000	17,000
16	Tellico.....	285	2.70	230	1.30	110	(4)	175	None.	.....	.....	90	.....	.....	5,000	5,000
18	Hiwassee.....	2,700	2.50	6,750	1.50	4,050	25	22	10,850	90	40	110	500	610	16,000	20,000	
17	do.....	2,205	2.50	5,520	1.50	3,310	45	40	16,350	245	500	220	284	500	20,000	30,000	
22	do.....	1,080	2.60	2,810	1.50	1,620	50	360	800	13	13	38	248	284	90,000	95,000	
20	do.....	1,050	2.60	2,740	1.50	1,580	110	100	2,700	71	30	82	166	248	28,000	32,000	
19	do.....	950	2.60	2,460	1.50	1,420	143	135	7,500	60	20	56	110	166	30,000	34,000	
31	do.....	400	2.60	1,040	1.50	600	80	60	3,320	78	40	110	.....	110	8,000	8,000

* Projects involve two developments with flume lines.

* Diversion.

The storage capacity of reservoirs in this table is calculated as though the basin were an inverted pyramid with base outlined by the flow line and with apex at the base of dam. The volume of impounded water is then obtained by multiplying the area of pool by one-third the height of dam. The assumed draw down, in acre-feet, is obtained by subtracting from the total storage the water which lies below the level of the assumed vertical draw down, and this last, in turn, is arbitrarily assumed in harmony with average practice in design. What is called the economic plant capacity (meaning the power-generating capacity that should be installed) is calculated on the basis of an efficiency of 80 per cent and a load factor of 50 per cent. If the project provides storage enough to completely regulate the run-off at the site, the calculation is based on the mean annual flow. If no storage is available, the calculation is based on one-half the mean annual flow. This last is considerably less than the "mean monthly minimum for the six high-water months." If the project provided limited storage, the calculation is based on the product of the mean annual flow multiplied by a factor lying between unity and one-half, and determined in value by the extent of storage available.

That the above basis leads to conservative estimates is shown by an analysis of the relations existing at plants already built. For example, at Parksville, on the Ocoee River, the mean annual run-off is very closely 1,350 second-feet. But to develop 25,000 horsepower at 80 per cent efficiency and with a 50 per cent load factor under the head available at the Parksville plant of the Tennessee Power Co. requires a flow of 1,400 second-feet. The available storage, 31,000 acre-feet, would yield a flow of 85 second-feet for six months per year. Although but little storage is available, therefore, the plant capacity was based almost exactly upon the mean annual flow of the river.

A similar analysis applied to a number of other plants, taken at random, shows that the operation of the plants at rated capacity, but with a load factor of 50 per cent, calls for percentages of the mean annual rate of stream flow ranging from 45 per cent to approximately 170 per cent. The figure which applies to the Tallulah Falls plant of the Georgia Railway & Power Co. is 166 per cent; to the Ninety-Nine Island plant of the Southern Power Co., 65 per cent; the Lock Twelve plant of the Alabama Power Co., 68 per cent; to the Saratoga Creek plant of the Mohawk Hydroelectric Co., 145 per cent. Inasmuch as most of these plants operate with load factors higher than 50 per cent, the ratio of requisite water supply to the respective mean annual rates of stream flow is actually much higher than the above figures indicate. The average of the load factors of 44 of the leading power companies of the country for the years 1915-1917 was 56.6 per cent; that of the Tennessee Power Co. was 73.4 per cent; and that of the Ontario Power Co., 91.5 per cent.

If future hydroelectric practice follows along the lines of present-day design, then it can be definitely said that the total hydroelectric power of the entire Tennessee River Basin above Chattanooga will exceed 2,000,000 horsepower.

POWER PROJECTS WHICH HAVE NOT MATERIALIZED.

So far as I know, only two large power projects have failed to materialize. In 1912 a group of men incorporated a concern under the name of the Tennessee Hydroelectric Co. and had a bill introduced in Congress to grant them the right to dam the Clinch River. The bill failed to pass. In 1908 the French Broad River Power Co. was incorporated to develop a site on the French Broad a short distance above its confluence with the Holston. By a ruling of the Acting Secretary of War in 1909, a permit would not have been required from Congress for the building of this dam. Both of these projects appear to have been purely speculative; and none but the most superficial field work seems to have been done in either case.

A project for the development of all the power of the Pigeon River and its tributaries is at present active, and probably initial construction will begin within a year. The project will develop some much-needed power, and it is to be hoped this power may be brought to Knoxville. The project will result in considerable stream regulation, but the exact amount can not be stated.

An important reason, if indeed not the chief reason, why water-power development is not more advanced in the Tennessee River Basin is the lack of such knowledge as this survey is intended to secure. By this is meant chiefly the lack of knowledge of the physical facts pertaining to water-power sites and prospects themselves. But more than this is intended. Lack of knowledge of the latent mineral resources which in many instances could form the basis of industries to utilize the water power; lack of a general comprehension of the favorable climatic conditions obtaining within the basin and of the excellent character of labor resident here are contributing factors. It can hardly be doubted that the acquiring of

this knowledge and its dissemination will greatly stimulate the industrial development of the region. Many of the cities within the basin are now seriously handicapped by the lack of available power at reasonable prices, and this is especially true of Knoxville. During the last three years the Knoxville Board of Commerce has received inquiries by the score from business concerns seeking desirable locations, where the principal desideratum was abundant power. It can scarcely be doubted that some important industries have been lost to the city or to the district because of this lack. Discrimination on the part of power companies in favor of certain localities is working out to the detriment of other localities which, if served on an equal basis, could utilize power to good advantage, but are now compelled to see prospective industries either held in abeyance or establish themselves in more favored localities. By developing the exact extent to which such conditions prevail the survey can render a service of more than local concern, for it is to the interest of the country at large that industries the country over shall be just as advantageously located as it is possible for them to be.

The proposed survey of the Tennessee River Basin can accomplish much by making a study of both the developed and the undeveloped water powers within the basin with a view to building up eventually a comprehensive program of consolidation of power systems into one single system, and of successively adding to present generating stations other developments, in the relative order of their commercial availabilities but in accord with a complete plan for the ultimate harmonious utilization of every foot-pound of possible power generation. Until the survey is complete, no power projects should be allowed to be undertaken by private initiative on any stream in the basin unless it is determined in advance that these projects will fit into such a comprehensive plan.

Judging from the advantages gained by the consolidation of power systems as effected of recent years in California and as reflected by the objects of the superpower survey in the Middle Atlantic States now being conducted by authority of Congress, there can be little doubt that eventually consolidation of the southern power systems will take place. In fact, the entire southern Appalachian region makes a natural power zone. Already most of the large power companies within this region are interconnected. This is true of the Southern Power Co., the Carolina Light & Power Co., the Columbus Power Co., the Georgia Railway & Power Co., the Central Georgia Power Co., and the Tennessee Power Co. The total installed capacity of the larger power companies within the southern Appalachian region to-day is in excess of 860,000 horsepower of hydroelectric and 200,000 horsepower of carboelectric power. More than 4,000 miles of transmission lines have been built.

It is a fortunate circumstance that the survey of the Tennessee River Basin has been authorized while yet probably 90 per cent of the latent water power is still undeveloped. This fact creates a valuable opportunity to forestall inept isolated power projects, and, unhampered, to study the basin and evolve a plan for the complete conservation of all the water power.

I would urge that such a study, if made at all, be made broad enough to cover the situation in all of its important aspects, including accurate surveys of power and storage sites, detailed studies of water supply, power market requirements, and land damages, and establish clearly the fundamental relation that exists in the Tennessee Basin between power development, the utilization of the local mineral resources, and the commercial use of the river.

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APPENDIX C.

REPORT ON GEOLOGY AND MINERAL RESOURCES, TENNESSEE RIVER BASIN.

From: Rolf A. Schroeder, Assistant Geologist.
To: Maj. Harold C. Fiske, District Engineer.
Subject: Geology and mineral resources.

GENERAL GEOLOGY AND TOPOGRAPHY.

The area under consideration in this report embraces the catchment basin of the Tennessee River and its tributaries, downstream as far as Paducah, Ky., comprising an area of some 40,000 square miles, and representing a great variety of geological formations ranging in age from the pre-Cambrian to the Tertiary; from complexly folded and highly faulted strata, associated with intrusives, in the east, to nearly horizontal, unconsolidated beds in the extreme west. This area may conveniently be

subdivided into three unlike provinces. The first, province A, extends from Chattanooga eastward; the second, province B, from that city down to Riverton, Ala.; and the third, province C, from the latter city to Paducah, Ky.

Province A: This area is a part of the great Appalachian Mountain system, comprising numerous high, parallel ranges which trend west-southwest, flanked on the west by the Valley of East Tennessee.

The eastern portion of province A is underlain by a core of igneous and metamorphic rocks of Cambrian age, such as granite, gneiss, and schist, forming high parallel ranges, the Unakas, which represent the topographic divide between Tennessee and North Carolina, and the Blue Ridge, which marks the eastern limit of the Tennessee River Basin. The streams here are in youth and precipitous, probably affording water power, but little navigation.

The central portion of province A, as far west as the western border of the Tennessee and Clinch River Valleys, known as the Valley of East Tennessee, is underlain by Paleozoic sedimentary rocks (limestones, shales, and sandstones) very much folded and faulted, and in some cases standing on end, which condition is also typical of the Sequatchie Valley. Some of these faults involve a vertical displacement of more than 1,000 feet. In some cases movement along the fault planes has ceased and the fault fracture has been cemented by mineral matter. Such healed faults would not constitute a menace to dam structures.

The topography in the Valley of East Tennessee is directly controlled by the geologic structure, the strata having been subjected to enormous pressure from the southeast, resulting in a series of parallel folds and overthrust faults. Drainage is rectilinear, the larger streams flowing parallel with the strike of the underlying strata. Recent uplift has resulted in rejuvenation of these streams and in entrenched meanders.

The western portion of this area, with the exception of the Sequatchie Valley and its escarpments, simulates province B, inasmuch as the strata here are nearly horizontal, only they are higher above sea level, forming the "Cumberland Plateau." The cap rock is sandstone of Carboniferous age.

Province B: This region is comparatively flat, comprising the Highland Rim, Cumberland Plateau, and a portion of the Central Basin. The rocks underlying this area are predominantly limestones and mostly Carboniferous in age along the Tennessee River, nearly horizontal, with a slight dip away from the Central Basin, and more or less elevated, especially so in the region known as the Cumberland Plateau. The lower reaches of the Tennessee River here are bordered by a large alluvial flood plain composed of unconsolidated clay and sand.

Province C: The river, where it runs northward across Tennessee, flows, for the most part, over unconsolidated rocks, Cretaceous and Tertiary in age, comprising sands and clays. Its direction parallels the strike of these strata, whose attitude is nearly horizontal, with a slight inclination westward. These rocks are more easily eroded than the unconsolidated rocks toward the east, and there is here a strong tendency for a lateral migration of the river toward the west.

Drainage.—The general drainage and valley pattern of the Tennessee River system is largely dependent upon the attitude of the underlying rocks. The direction of flow of the main streams is nearly universally parallel to the direction of strike of the bedrock strata, excepting where the bedrock is granite or other homogeneous rock as in the Unaka Range and the Blue Ridge. This control upon topography is very striking in Virginia, in the Valley of East Tennessee, and in northeastern Alabama, where the Tennessee River and its chief affluents run in a direction parallel to the trend of major folds and faults, the valleys often marking the axes (crests) of anticlines. The smaller tributaries and a few of the larger ones, such as the Hiwassee and Watauga, flow parallel to the dip, resulting in a rectangular drainage pattern. The parallel folding and faulting of the strata flanking the Appalachians, therefore, is the dominant factor that controls the direction of flow of the Tennessee River as far south as Guntersville, Ala. Another large structure controls its course from this point downstream to Paducah, Ky., namely, the Nashville Dome, an enormous structural uplift, whose topographic expression is the Central Basin of Tennessee (the valley, as usual, being anticlinal). Since the strata dip radically from the center (near Murfreesboro), the strike of the rocks is not a straight line but is concentric. The Tennessee River flows through northern Alabama and across Tennessee parallel to the strike and consequently in a huge semicircle, rather unsymmetrical, to be sure.

Caves, sinks, and subsurface passages.—Certain rocks are much more soluble in surface waters than are others. Prominent among the former are limestones, dolomites, gypsum, and salt, and by far the majority of solution passages which occur in the Tennessee River Basin are found in limestones such as the Chickamauga limestone and Knox dolomite of the Ordovician, and the Newman limestone of the Mississippian

formation. "Sinks" are depressions of the land surface produced by the enlargement of vertical solution channels, such as joints and other fractures, and more rarely are formed by the collapse of the roofs of caves. Sinks occur along the Clinch and Powell Rivers in elongated zones parallel to the river and marking the outcrops of pure, soluble limestone strata. They are especially well developed near Dungannon, Cleveland, and Lebanon, Va., and are also quite common in the middle section of the Tennessee River Basin, in northern Alabama. A few sinks are scattered throughout the Valley of East Tennessee. In short, they may be found wherever soluble phases of limestone formations occur above ground water level. Where engineering works are contemplated, it is important to locate sinks and to ascertain the direction and character of the subsurface drainage, its relation to prospective reservoir sites, and the configuration of caves and underground passages that may be associated with such sinks. In strong contrast with these limestone regions are the large areas of the Tennessee River Basin included in the mountain sections of eastern Tennessee and western North Carolina, where sinks, caves, and the like are unknown. These sections are underlain by massive, crystalline, insoluble rocks, such as granites, gneisses, schists, and quartzites, and these rocks would afford foundations for reservoirs and dams, in which underground passages for water need not be feared.

Caves and subterranean streams originate in the same manner as sinks—that is, by solution of limestones along natural fractures, and therefore are common in the same formations with sinks. When such an underground stream emerges, it is called a "big spring," and such springs are very common in certain regions, notably above ground water level in rocks underlying the Cumberland Plateau and its outliers, in Tennessee and Alabama. A typical "big spring" of this sort is the famous Huntsville Spring, in northern Alabama, which flows 20,000,000 gallons per day. Another such is Big Cave, in Jackson County, where a large spring emerges from a cave; the water is used to run a gristmill and then disappears in a sink hole.

Among the more important caves of this region are the Monteagle Wonder Cave, in Marion County, Tenn.; the Cadle Cave, in the Powell River Valley, 6 miles southeast of Cumberland Gap, and the Shelta, Bangor, and Dorans Caves, in northern Alabama. Big springs and subterranean passages are common along the edges of the plateau mountains of northeastern Alabama and east central Tennessee, but are rarely if ever encountered in the eastern tributaries of the Tennessee River in the highlands of the southern Appalachians.

MINERAL DEPOSITS.

There occur within the limits of the Tennessee River Basin at least 50 mineral substances of economic value, comprising nine metallic ores, more than 30 nonmetallic minerals, and 10 rocks. This does not include a great variety of other minerals and rocks which have been observed in this region, but which so far have not been exploited. A description of the more important mineral resources is given in the following pages, together with brief statements as to their occurrences, principal uses, and statistics of production.

Among the more important ores are those of iron, copper, zinc, manganese, silver, and lead. The production of coal and coke outranks in value that of any other substance mined in the basin. Next in value is the production of phosphate, copper, and iron. Clay, limestone, and marble are extensively quarried, and undeveloped deposits of slate and granite underlie several thousand square miles in the mountain region.

Among the nonmetallic minerals which occur in large quantities and which have contributed considerably to the country's production, may be mentioned barite, feldspar, mica, pyrite, salt, and gypsum.

Mineral substances which enter into the manufacture of sulphuric and phosphoric acid, artificial abrasives, lime and cement, dyes, steel and ferroalloys, and ceramics are available in abundance in the Tennessee River Basin. The total present annual production of raw mineral within the Tennessee River Basin approximates \$36,000,000.

Abrasives (natural), corundum, etc.—The only abrasive produced in considerable quantities within the Tennessee River Basin is corundum, an oxide of aluminum. This mineral is surpassed in hardness only by the diamond and is in great demand for the manufacture of emery wheels, paper, powder, etc. Emery is a mixture of black, massive corundum with magnetite or hematite, and its value as an abrasive is due to the percentage of corundum it contains, for the latter does the cutting. The raw corundum must be crushed and ground before it can be used, and no doubt electric power for this purpose would be welcome in western North Carolina. The deposits are in Clay, Macon, and Jackson Counties, on the headwaters of the Tuckasegee and

Little Tennessee Rivers. (See Chart III.) The annual production has fluctuated in value between \$10,000 and \$60,000. Lack of transportation facilities has hindered development.

Garnet, in small quantities, is ground for abrasives near Shooting Creek, Clay County, N. C., on the headwaters of the Hiwassee. Quartz and feldspar are sometimes ground to make sandpaper and scouring soaps.

Millstones, made from granite, conglomerate, and garnet-schist, are produced locally in the mountainous regions of eastern Tennessee and western North Carolina.

Flint, cut as dimension stone, has been used near Iron City, in the west central Tennessee Basin, to make tube mill liners.

Tripoli, suitable for polishing powder, occurs near Butler, Tenn., in the Watauga River Basin, and in Wayne County in the west central Tennessee Basin. It has also been mined in Sullivan County in the Upper Holston Basin, but no production is reported at present. (See Chart IV.)

Abrasives (artificial), carborundum, etc.—"Carborundum" and other silicon carbides are made in the electric furnace by fusing together quartz sand, charcoal, and sawdust. Similarly, "alundum" is made from bauxite. These raw materials are all available in the Tennessee River Basin, and artificial abrasives could be made here if cheap electric power were available. At the present time the industry centers at Niagara Falls.

Asbestos.—"Asbestos" is a term rather loosely applied to a number of different minerals having a fibrous structure, the two important ones in this country being chrysotile and amphibole. Chrysotile is a silky, fibrous mineral occurring as veins in basic rocks such as those which flank the granite core of the Appalachians from Canada to Alabama. Amphibole is similar but its fibers are generally longer and not so readily spun into asbestos fabric; it is generally considered inferior. The asbestos of northeastern Georgia is a variety of amphibole, known as anthophyllite.

Although no large deposits of asbestos minerals are known to occur in the Tennessee River Basin, certain small outcrops are found on the headwaters of the Tennessee River in North Carolina, and these may some day be developed and prove to be of commercial significance. So far no asbestos has been mined commercially within the limits of the Tennessee Basin. In Georgia some deposits are mined just south of the divide. Georgia has ranked with the largest producing States, but the United States, as a whole, is a small producer, being credited in 1919 with only 1,412 tons, or about 1 per cent of the world's production. It is, however, the world's largest manufacturer of asbestos products. The imports in 1919 amounted to 135,530 tons, valued at \$7,369,685, obtained largely from Canada, which country in 1919 produced 88 per cent of the world's output. The Georgia deposits now being worked are at Sall Mountain, about 20 miles south of the Tennessee River Basin and a mill at Gainesville treats this asbestos, which is rather low grade and can not be spun. Virginia has produced small quantities in the past and there is a mill in Bedford County about 30 miles north of the Tennessee River divide. Although the demand for crude asbestos is great, the abundance and excellent quality of the Canadian product mitigates against the rapid development of domestic deposits.

Barite.—Barite, or barium sulphate, is a heavy crystalline mineral, occurring in Virginia, eastern Tennessee, and north central Georgia in residual clays overlying limestones and dolomites.

The largest producing State in this region is Georgia, where extensive deposits are exploited near Cartersville, Bartow County, south of the Tennessee River Basin. Next in importance are the deposits of the Tennessee Basin, which have been especially developed near Sweetwater, Tenn., in regions rather remote from any large river, and it has also been mined near Del Rio, 40 miles east of Knoxville, on the French Broad River. (See Chart III.) Barite has been mined in Virginia, along the southern slope of Kent Ridge, between Tazewell and Honaker, along the Clinch River, and near Marion, on the Holston River. The present producing deposits in Virginia are east of the Blue Ridge, outside the basin. A small production is also reported from deposits in Madison County, N. C., in the French Broad Basin. Although the chief market for barite is located in northern States, good markets have recently developed at Charleston, W. Va., at Sweetwater, Bristol, and Johnson City, Tenn., and Cartersville, Ga.

Barite is used chiefly as a pigment in making mixed paints, as a filler for paper, rubber goods, linoleum, and oilcloth. "Lithopone" is a compound prepared from 70 per cent barite and 30 per cent zinc sulphide. It is used to make "flat" wall paints, which are now extensively used as a substitute for wall paper. Barite pigments do not blacken as do those prepared from white lead. "Lithopone" and allied pigments are sold under a great variety of trade names, such as "Beckton White,"

"Ponolith," "Zincolith," "Marbon White," etc. Barite is also extensively used in the manufacture of hydrogen peroxide, and other chemicals.

The production of barite in 1919 in the United States is estimated at 190,000 tons, valued at \$1,454,000, of which 33,111 tons originated in the Tennessee River Basin.

Bauxite (aluminum ore).—Bauxite is an earthy, soft, friable substance composed of hydrous oxides of aluminum, and is the chief ore of aluminum. Although the largest plant in the United States for the reduction of aluminum ore is located near the Tennessee River, none of the bauxite mined in the Tennessee Basin is treated there; in fact the production of this mineral within the limits of that basin has been comparatively small, although several bauxite deposits are located there.

Arkansas is the leading producer. The deposits in Georgia and Alabama are extensive, but are not within the Tennessee River Basin. Of the deposits in Tennessee (see Chart III), one is located at the base of Missionary Ridge, east of Chattanooga. It has been worked in the past for making alum, but natural difficulties in mining have hindered production, and more than half the bauxite now used for this purpose comes from mines in Georgia. Some ore has been shipped from another deposit near Hixson, Tenn., to St. Louis and to abrasive producers at Niagara Falls. Deposits near Elizabethton, Carter County, in eastern Tennessee, have been intermittently worked in the past.

Bauxite is in great demand by aluminum metal producers, but more than one-third is used by makers of chemicals, abrasives, and high-alumina refractories. The mineral can be made into very hard brick for furnace linings. The plant of the Aluminum Co. of America at Alcoa, Tenn., reduces alumina, the oxide of aluminum, which is shipped in by rail from St. Louis, at which latter point bauxite ores from Arkansas, Georgia, and South America are treated. Bauxite is extensively used to make "alundum" and other artificial abrasives, consisting of alumina. The process involves the use of the electric furnace and the industry centers at Niagara Falls. The nearness of the Georgia and Arkansas deposits to this region should be conducive to the production of artificial alumina within the Tennessee River Basin.

The production of bauxite in the United States in 1919 was 376,566 long tons, which had a value at the mines of \$2,202,747, to which Arkansas contributed about 90 per cent. Prices range from \$5.45 to \$12 a long ton. According to the State bureau of mines report, Tennessee in 1919, produced 1,500 long tons, valued at \$9,000, representing an average value of \$6 per ton. The only producing deposit according to the report of the State mine inspector was that at Missionary Ridge, but the United States Geological Survey reports operations at Elizabethton, Carter County, Tenn. Tennessee production in 1919 represents about 2.3 per cent of the total production in the United States in that year. The value of primary aluminum produced in the United States in 1919 was \$38,558,000.

Building stone.—Beds of workable marble, especially suitable for interior decoration, are found in a belt in the Valley of east Tennessee, extending northward from Monroe County across Tennessee into Virginia. Another belt, parallel to this one, passes through Cherokee County, N. C., and extends southward into Georgia, where it is quarried in Pickens County. The commercial marble of Tennessee (Holston marble) occurs as lentils in the much folded and faulted strata of the Chickamauga formation which is exposed in the Tennessee and Holston River Basins. (See Chart II.)

In 1918, three States produced 82 per cent of the total output of marble for the country: Vermont, 50 per cent, Georgia, 21 per cent, and Tennessee 11 per cent.

The production of marble in Tennessee in 1919 amounted to 560,972 cubic feet, valued at \$643,499, a steady decrease since 1914, attributed to a shortage of labor. The United States Geological Survey reports a production of 36,450 short tons of marble originating within the Tennessee River Basin in 1919.

Limestone suitable for building stone, paving, and flagging is very abundant in the limestone formations throughout the State. Other uses of limestones are for furnace flux, fertilizer, lithographic stone, and in sugar, paper, alkali, and glass works. Large quantities are burned to make lime and cement. It is also used to prepare calcium carbide in the electric furnace. Limestones produced in Tennessee in 1919 amounted to 425,494 long tons, valued at \$425,344.

A large oolitic limestone quarry for dimension stone is operated near Russellville, Ala., where 8,000 cubic feet of limestone are quarried per month under normal conditions. It is shipped to all the important southern cities. Approximately 10,000 tons per month of broken stone are shipped to Sheffield, Florence, and other centers of iron industry to be used as flux.

Granite, and other granitic rocks of Archean Age, form the core of the Appalachian Mountain system, marking the highest crests from the Canadian line down to Alabama.

(See Chart II.) This rock is in great demand when fine grained for monumental purposes, on account of its extreme hardness and resistance to weathering. Large amounts are also used for building stone, paving blocks, curbing, crushed stone, etc. The granitic areas in the Tennessee Basin are at present somewhat inaccessible. Electric power is generally used, when available, in the cutting sheds and quarries.

The only production in the Tennessee River Basin is in North Carolina, and by far the larger part of the production in that State comes from points east of the divide. North Carolina in 1917 produced granite valued at \$1,486,541. Several quarries are operating near Asheville, and recently near Hendersonville in the French Broad River Valley. A large area of dark-colored, medium-grained, epidote-biotite granite extends southwest from Hot Springs, Madison County, N. C. It has not been exploited but promises well. A few quarries have recently been opened on Ripshin Mountain, Tenn., where a dull-pink biotite granite is found. This region is rather inaccessible and is drained by Doe River.

Slate suitable for roofing occurs in a belt extending northeastward through Monroe, Blount, and Sevier Counties in Tennessee, in the basins of the Little Tennessee, Little, and Little Pigeon Rivers, and a similar belt is found in north central Georgia south of the Tennessee River Basin. (See Chart II.) The Tennessee deposits have not yet been thoroughly exploited, but should, in time, prove to be of value. Two formations in this region contain beds of slate, the Wilhite and Pigeon slates. The former is too soft for commercial use, but has the necessary hardness, evenness, and cleavage along Little Pigeon River, along which stream it is well exposed over great areas. The Pigeon slate has been developed somewhat along the Little Tennessee River. It is a fine, even-grained rock with good cleavage, and resists weathering well, as shown by the high, sharp slate cliffs and ridges that border the river where it crosses this formation. Its thickness is from 1,300 to 1,700 feet. Much good slate has been shipped from a quarry 3 miles southeast of Chilhowee, Tenn.

Clay.—Clay is a very abundant and widely dispersed substance in the southern Appalachian region. High-grade ball clay suitable for the manufacture of china, enamel ware, insulators, crucibles, refractories, etc., is found in flat-lying lenses interstratified with loose sands in Henry and Carroll Counties, west Tennessee. (See Chart III.) About 40,000 tons are mined annually and are shipped to ceramic centers in Ohio, Delaware, New Jersey, etc.

Ball clays carry from 30 to 35 per cent alumina. Clay, however, is not at present valuable as an ore of aluminum, but may become so if an economical process can be devised for its reduction by means of the electric furnace. Residual deposits of kaolinite or china clay are found in decayed pegmatites, associated with granite in the high ridges forming the Tennessee-North Carolina divide. Several mines are in operation in Mitchell, Yancey, Swain, and Jackson Counties. These deposits of kaolinite lie in the headwaters of the French Broad River, and a considerable quantity of both clay and feldspar are shipped to Erwin and Johnson City, Tenn. Two companies at Erwin use some of these clays in making china and electrical ware. The Carolina, Clinchfield & Ohio Railway shipped about 350 carloads of kaolinite in 1920.

Lower-grade clays, used in the pottery and brick industries, are very abundant and may be encountered anywhere in residual limestone soils. Bricks are generally made and consumed near or in the larger cities. Bricks and terra cotta are made at Kingsport.

The principal clay-working region in Alabama is in Jefferson County. Common bricks are made in Montgomery and Talladega Counties.

Tennessee in 1919 produced 23,280 short tons of clay, valued at \$90,159. Clay products, valued at \$2,308,731, were made in the same year.

Chrome and nickel.—Chromite, the chief ore of chromium, and genthite, a nickel ore, occur together in western North Carolina, but the production so far has not been great.

Chromium and nickel are in demand by manufacturers of ferro-alloys. Some chromium was produced in North Carolina during the war and shipped to various States. Nickel, in small quantities and of low grade occurs near Webster, N. C., and large investments were once made in these deposits. Chromite, however, does exist in commercial quantities and could be used in the electric furnace to make ferro-chrome, provided cheap power were available. Deposits of this mineral are known to occur in North Carolina, in Watauga County, in the Watauga River Basin; in Yancey County, in the Nolichucky Basin; in Buncombe County, in the French Broad Valley; and in Jackson County in the Tuckasegee Valley. (See Chart III.)

Five mines were in operation in North Carolina in 1918, and 339 tons of ore were produced within the headwater regions of the Tennessee River Basin. The ore is high grade, containing more than 45 per cent chromic oxide.

Coal.—The coal fields of the Tennessee River Basin represent the southern portion of the great Appalachian coal measures, which flank this mountain range on the west from Pennsylvania to central Alabama. They form the western boundary of the Tennessee River Basin from the headwater regions near Tazewell, Va., south to Chattanooga, at which point the main stream cuts into this Cumberland Mountain coal field and flows through it to Guntersville, Ala. The river then turns westward, leaving the coal field and entering the great limestone area of middle Tennessee and northern Alabama. (See Chart I.)

This great coal field is a mountainous plateau about 50 miles wide, with an average elevation of 1,000 feet above the level of the main river valley. The Tennessee River parallels the eastern escarpment at a distance of 5 to 15 miles, and its lateral valleys cut into the coal field, forming gaps through which streams and railroads find their way to the valley proper.

There has been a great development here, and mines are operating wherever the railroads traverse the coal measures. The production of coal in the Tennessee River Basin in 1919 was 19,670,000 tons. There are still large areas underlain by coal but not supplied with railway facilities and where its full extent and quality are not fully known. Large additional coal areas will be opened up when new railroads are constructed and when navigation is developed on the headwater streams draining these regions, where it is thought that facts yet to be obtained will show this to be feasible, and this development should be anticipated and preparations made before the demands of industry for fuel increase in this section. The estimated coal reserves in Tennessee alone, as published by the Tennessee Geological Survey, are over 25,000-000,000 tons, which can be made available to future industries located in the Tennessee River Basin.

In 1919, 1,080,000 tons of coke were produced, the two big coke-producing centers being near Norton, Va., in the Powell River Basin, and Whitwell and Tracy City, Tenn., in the lower Sequatchie Basin, where the well-known Sewanee coking coal occurs. There are additional deposits of this coking coal awaiting transportation facilities, while in other places fine bituminous coal, not, however, suitable for coking, also awaits exploitation.

In the coking-coal districts, industries are beginning to use the benzol and toluol obtained from the coal-gas ovens, but so far none has been treated electrolytically to obtain dyes and nitrates, the latter always being in demand by the fertilizer industries. The long list of coal by-products, such as coal gas, coal tar and its derivatives, ammonium sulphate, etc., are produced, but more of these products are now being wasted at a time when the development of this section calls for their conservation and use for local industries at points where raw materials and cheap power are available in abundance.

Detailed statistics for coal and coke production in Tennessee in 1919 are given below:

Rank of coal-producing counties of Tennessee in 1919.

County.	River basin.	Tons.	Value.
Campbell.....	Clinch and Powell.....	1,138,327	\$3,332,560
Claiborne.....	Powell.....	1,109,455	2,796,854
Grundy.....	Partly Elk.....	551,880	1,624,915
Anderson.....	Clinch.....	503,057	1,395,300
Marion.....	Sequatchie and Tennessee.....	356,268	1,010,862
Fentress ¹.....	.....	340,076	799,053
Morgan.....	Emory.....	336,786	869,752
White ¹.....	.....	273,187	652,412
Hamilton.....	Tennessee.....	238,838	501,787
Overton ¹.....	.....	194,174	399,304
Roane.....	Tennessee.....	149,216	404,491
Others.....	.....	196,342	357,010
Total.....	.....	5,387,606	14,244,300

¹ Not within the Tennessee River Basin.

Rank of coke-producing counties in Tennessee in 1919.

County.	River basin.	Tons.	Value.
Campbell.....	Clinch and Powell.....	55,700	\$329,845
Roane.....	Middle section of Tennessee.....	54,108	419,337
Grundy.....	Lower Sequatchie and Elk.....	20,535	154,027
Morgan.....	Emory.....	4,480	29,337

Copper, pyrite, sulphuric acid, gold, and silver.—Copper is mined near Ducktown, Polk County, Tenn., in the headwaters of the Ocoee River. (See Chart III.) The ore is low grade and consists of sulphide minerals, such as pyrrhotite, chalcopyrite, sphalerite, and galenite. The gangue contains much pyrite. In roasting the ore enormous quantities of sulphuric acid are obtained, largely as a by-product. The Tennessee Copper Co. operate a 2,000-ton smelter, converter, and sulphuric-acid plant. The ore comes from two mines near by and a small quantity from a mine in Fannin County, Ga. The Ducktown Sulphur, Copper & Iron Co. operates two 500-ton blast furnaces on sulphide ore from mines near Isabella, Tenn.

Sulphuric acid is used in large quantities to treat the phosphate rock mined in the Duck River Valley. (See Chart III.) It is also in great demand for the manufacture of other acids, explosives, and in oil refining, steel galvanizing, bleaching, tanning, etc.

Gold and silver are obtained as a by-product in the mining of copper. Small quantities of gold have been mined in the past in Monroe and Blount Counties, Tenn., but this gold is placer gold and no production is reported since 1905.

Pyrite occurs in Fannin County, Ga., south of the Ducktown deposits. (See Chart III.) It has also been reported near Otto, Macon County, N. C., but this vein has not been exploited. The Virginia pyrite deposits are not within the Tennessee River Basin, and the same may be said of the North Carolina gold and copper fields.

The production of copper in Tennessee in 1919 was 15,727,867 pounds, valued at \$2,538,703, originating in the Ducktown district. In the same year there were produced 368,898 short tons of sulphuric acid, valued at \$2,468,598; 57 fine ounces of gold, valued at \$1,104; and 43,433 ounces of silver, valued at \$46,540. Tennessee in 1919 ranked eighth as a copper-producing State and is credited with 1.2 per cent of the total output in the United States.

Feldspar, quartz, mica, and gem stones.—Feldspar occurs together with quartz, mica, kaolinite, and gem stones in rocks known as pegmatite, associated with granite, in the west slope of the Blue Ridge and the east slope of the Black Mountains in Mitchell, Avery, and Yancey Counties, N. C., on the headwaters of the Nolichucky River. (See Chart IV.) Pegmatites also occur in Virginia, Georgia, and Alabama in regions remote from the Tennessee River Basin. Feldspar is used by the potteries and enamel, china, and electrical ware manufacturers. Although its principal use is in the ceramic industry, some is also used as a binder for emery wheels, as an abrasive, for poultry grit, etc. The principal markets are at Trenton, N. J., East Liverpool, Ohio, and Wilmington, Del. The United States is the largest producer and is credited in 1918 with a production of 88,498 tons. North Carolina ranked first in quantity and second in value of its production of feldspar in 1918. The production of crude feldspar was 35,732 long tons, valued at \$160,275. At present North Carolina crude is quoted at \$7 to \$8 per ton f. o. b. mines. Some of this spar was ground in mills at Erwin, Tenn., on the North Toe River. The Carolina, Clinchfield & Ohio Railway expects to ship about 70,000 tons of feldspar during 1920.

Quartz and quartzite (recrystallized sandstone) are abundant in the mountains of the Southern Appalachians. Purple, transparent quartz is valuable as a gem stone (amethyst), but quartz is nearly always opaque or slightly translucent and of value only as a flux in copper smelting, or in glass and pottery making, and as an abrasive. Its market value is low and it can not be transported far. Some quartz is mined near Murphy, N. C. A low-grade quartz is mined near Ducktown, Tenn., for use as a flux in copper smelting and in acid towers. Vein quartz from Mendota, Va., is marketed at Bristol, Tenn., for use in polishing and cleaning compounds.

Mica occurs together with feldspar and quartz in the pegmatites of the Appalachian system from Canada to Alabama. The deposits in North Carolina are found in Mitchell, Avery, and Yancey Counties on the headwaters of the Nolichucky River, and are classed with the most important of the country. (See Chart IV.)

Mica is valuable on account of its perfect cleavage, elasticity, and nonconductivity of heat and electricity, a combination of properties in which it is unsurpassed by any other abundant mineral. Mica rarely occurs in sheets of considerable size and about 90 per cent of the mica produced is scrap and must be ground. Sheet mica is worth five to seven times as much as scrap mica, and the chief consumer is the electric industry. It is used in the manufacture of dynamos, condensers, mica-board, telephones, spark plugs, stove fronts, lamp chimneys, phonograph diaphragms, etc. Ground mica is used to make insulators, fire-proof paints, lubricants, wall paper, artificial snow and stone, roofing, etc.

Sheet mica valued at \$1,488,769 was imported in 1919, largely from Canada, Brazil, and India. North Carolina led all other States in the quantity and value of mica pro-

duced in 1918, amounting to 1,517 short tons, valued at \$473,380. Some scrap mica and mica schist are ground at the mines, but this part of the industry is not remunerative unless sheet mica is also produced. Sheet mica of the higher grades sells as high as \$8 per pound.

Gem stones such as beryls, including aquamarine and emerald, amethysts, garnets, rubies, and sapphires are mined in the mountains of western North Carolina. Some of these are obtained as a by-product in the mining of feldspar, mica, and corundum.

Graphite.—Although geological conditions appear to be favorable for the occurrence of commercial deposits of natural graphite in the eastern headwaters of the Tennessee River Basin, only small quantities have been found up to the present time in the mountainous regions of North Carolina and east Tennessee. Large deposits occur in Clay County, Ala., about 60 miles south of the Tennessee River Basin, and nearly 8,000,000 pounds were produced in this district in 1918. Large quantities of graphite are annually imported to this country from Ceylon and Madagascar, to be used together with ball clay to make graphite crucibles so essential to the steel industry. Graphite is also used to make foundry-facings, electrodes, lubricants, pencils, dry batteries, and paints. With the immense potential electric power of this region, the possibility of making artificial graphite is well worth considering. It is now produced in large quantities at Niagara Falls, N. Y., by means of the electric furnace, anthracite and petroleum coke being the raw materials used. Such substances are just as available here as elsewhere and the production of artificial graphite should be a profitable industry in the Tennessee River area when cheap electric power for this purpose can be obtained.

Iron ores.—Iron ores mined in the Tennessee River Basin are of three kinds, red, brown, and black. Of a total of 60,466,000 tons mined in the United States in 1919, 538,000 tons originated within the Tennessee River Basin. It has been estimated that there are 500,000,000 tons of reserve iron ore in Tennessee, most of which underlies areas drained by the Tennessee River system, giving a potential production for this region much in excess of the actual production. (See Chart I.) Investigation of the future possibilities of these deposits is recommended.

Beds of red iron ore or fossil hematite of Silurian age are exposed in parallel belts flanking the Appalachians from New York to Alabama. The southern field centers at Bessemer, Attalla, and Birmingham, Ala., but a considerable iron industry is centered at Rockwood and LaFollette, Tenn. (See Chart I.) Several hundred thousand tons of red ore are mined annually from beds of the Rockwood formation outcropping in this vicinity at the base of the Cumberland escarpment, on the right bank of the Clinch River. The pig iron produced annually in this district amounts in value to about \$3,000,000. The production of hematite in Tennessee in 1919 was 220,849 tons, which figures represent the larger part of the production of red ore in the basin. Extensive deposits of coal and limestone overlie the ore beds and are used in smelting the ore.

Brown iron ores are composed of hydrous oxides of iron, such as limonite and goethite, and occur as irregular masses, pockets, and beds in residual clay. Deposits of this kind are found in widely scattered localities in the Tennessee River Basin (see Chart I) and are being worked especially in west-central Tennessee, in areas drained by the Duck River and the middle and lower sections of the Tennessee River in Wayne, Hickman, Lewis, and Maury Counties. Four furnaces are located in this district. Another large deposit of brown ore, developed near Russellville, Ala., is situated on the divide between the lower and middle sections of the Tennessee River. The production of brown ore in Tennessee in 1919 is estimated at 85,000 tons. Alabama in the same year is credited with 194,000 tons, originating in the Tennessee River Basin, probably all coming from a few mines near Russellville. The shipping of coke to these western deposits from the coal fields makes their development more expensive than that of deposits in east Tennessee.

Black iron ore, or magnetite, oxide of iron, occurs in a large ore body near Cranberry, N. C., on the headwaters of the Doe River. The Cranberry mine in 1918 produced 60,326 tons of ore, which was smelted at furnaces in Johnson City, Tenn. The East Tennessee & Western North Carolina Railroad handled much of this ore and reports transporting 27,140 tons between January 1 and July 1, 1920.

The following table shows the production of pig iron in Tennessee in 1919:

Production of pig iron in Tennessee, 1919.

County.	River basin.	Ore treated.	Pig iron produced.	Value of product.
		<i>Long tons.</i>	<i>Long tons.</i>	
Roane.....	Tennessee and Clinch.....	165,308	71,164	\$2,124,957
Campbell.....	Clinch and Powell.....	61,058	32,033	891,437
Washington.....	Watauga and Nolichucky.....	37,119	17,711	837,648
Dickson.....	Partly Duck River.....	37,612	16,926	593,763
Wayne.....	Tennessee and Buffalo Creek.....	26,896	13,707	436,624
Lewis.....	Buffalo Creek and Duck River.....	28,464	13,848	436,877
Maury.....	Duck River.....	7,321	3,908	410,770
Hickman.....	do.....	2,986	1,375	32,721
Montgomery.....	Not in Tennessee River Basin.	27,550	15,565	-----
		394,474	186,237	5,766,797

List of furnaces operating in Tennessee in 1919.

Name.	Town.	County.	River basin.
Lafollette Coal & Iron Co....	Lafollette...	Campbell...	Big Creek. Tributary of Clinch River.
Standard Iron Co.....	Goodrich.....	Hickman.....	5 miles from Duck River.
Napier Iron Works.....	Napier.....	Lewis.....	Buffalo River. (Tributary of Duck River.)
J. J. Gray, jr.....	Rockdale.....	Maury.....	15 miles from Duck River.
Roan Iron Co.....	Rockwood.....	Roane.....	4 miles from Tennessee River.
Cranberry Furnace Co.....	Johnson City.	Washington.	3 miles from Watauga River.
Bon Air Coal & Iron Corporation.	Allens Creek	Wayne.....	2 miles from Buffalo River. (Tributary of Duck River.)

Elements which are used in the manufacture of ferro-alloys by means of the electric furnace are available in the Tennessee River Basin. Large deposits of phosphate, manganese, and sandstone are conveniently located for the manufacture of ferro-phosphorus, ferromanganese, and ferrosilicon. Chromite from North Carolina has been used considerably for making ferrochrome. Other elements occurring in this region and used to make ferro-alloys are aluminum, nickel, zirconium, cerium, and thorium. Ferrosilicon is now being made at Chattanooga.

Lime and cement.—The Tennessee River Basin, with the exception of the eastern headwater region, is favored with immense deposits of high-calcium limestone and marble (see Chart II) suitable to burn for lime; also shales and clays, which can be used with these in the manufacture of Portland cement.

Lime is used to make mortar and plaster for building purposes and in chemical works, paper mills, tanneries, sugar and glass works, etc. Cement is prepared by grinding together and burning limestone and shale, or argillaceous limestones, and is used chiefly to make concrete. Considerable amounts of potash are now being recovered as a by-product in the manufacture of cement.

Raw materials generally used for making lime and cement are the Holston marble, Chickamauga limestone, and the Knox dolomite, outcropping in the valley of east Tennessee. Very pure limestones of Carboniferous age underlie the Cumberland Plateau, and natural exposures of these formations are abundant along the Tennessee and Sequatchie Rivers. Fine oolitic limestones occur in great abundance along the Tennessee River above Guntersville, Ala. Lime and cement industries could in many cases locate their quarries close enough to the river to ship the manufactured products by water. Lime plants are now in operation at Bristol, Knoxville, Sherwood, etc. The cement industry at the present time is centered at Kingsport and Richard City, Tenn. Lime produced in Tennessee in 1919 amounted to 86,034 short tons, valued at \$585,751. The production of Portland cement originating in the Tennessee River Basin in 1919 is estimated by the United States Geological Survey at 1,750,000 to 2,000,000 barrels.

Manganese.—This element occurs in a number of minerals. The usual deposits consist of black, earthy masses of pyrolusite and similar minerals occurring in clays and frequently associated with iron ores. Extensive deposits of this kind are found in elongated areas, parallel to the Appalachians, from Virginia, through eastern Tennessee, into Georgia. (See Chart IV.) Manganese is an essential element in the steel industry. More than 95 per cent of ore mined is added to steel in the form of

alloys, ferromanganese, and spiegeleisen, the production of which involves the use of the electric furnace. Fourteen pounds of this alloy is added to every ton of steel produced by the Bessemer or open-hearth process. Small amounts of high grade ore are used to make electric batteries.

In the United States prior to the war, manganese production amounted to about 4,000 tons annually, but a sudden impetus was given to production in 1915 culminating in 1918, when 305,869 tons of high grade ore were produced, valued at \$8,240,386. With the end of the war, the demand for manganese has greatly subsided and a corresponding slump in production followed. The United States Geological Survey estimates the production of high grade ore in the United States in 1919 at 58,243 tons, of which 253 tons were produced within the Tennessee River Basin. However, this industry may revive when the market conditions become more stabilized. Prior to the war the manganese market was largely supplied by Russia and India, and the fate of the mining industry here is dependent upon future competition from these sources.

Phosphate rock.—Phosphate of lime, used extensively to make fertilizers, is mined in central Tennessee in Maury and Hickman Counties in the Duck River Valley (See Chart III.) It occurs as concretionary masses and beds in the residual soils of this region. Tennessee in the past has ranked next to Florida in the production of phosphate rock, and these deposits have contributed an enormous amount of the country's production. Lower grade phosphate occurs in Johnson County, Tenn., but prospecting here may prove the existence of larger and better rock. Besides its use as fertilizer, it is also used to prepare phosphorus by means of electrothermal processes, and to make phosphorsteel, which industry should flourish in this region on account of the large local deposits of both iron and phosphate.

It has been estimated that there are 88,000,000 long tons of phosphate rock reserves in Tennessee. Poor transportation facilities have retarded the production of rock in the Tennessee fields. If the Duck River were made navigable, a new outlet would be given, opening new markets toward the West.

Over half the total domestic production of phosphate in the United States was exported before the war, but the quantity has decreased from 1,300,000 tons in 1913 to 143,455 tons in 1918. The production in 1918 in the United States was 2,490,760 long tons, valued at \$8,214,463, and in 1919 the production is estimated at 1,941,700 long tons, valued at \$10,335,900. Tennessee production in 1919 amounted to 867,283 long tons, valued at \$3,594,683, an increase in value of \$2,495,775 over 1918 and represents about 45 per cent of the total output for the United States.

Sand, gravel, and broken stone.—Extensive deposits of sand and gravel are found in west Tennessee, where practically the entire State west of the river is underlain by loose sand formations. Sand and gravel are also abundant along the larger river courses of the basin, where these materials occur as flood plain deposits and river terraces. Friable sandstones sometimes yield glass sand. Such strata are found at various levels in the rocks of the Cumberland Plateau and in the folded beds of the valley of east Tennessee and southwestern Virginia.

Sand is used when white and pure in glass making. It is also used to make concrete and mortar for molding; as a flux in the iron and steel industry; to produce friction under locomotive wheels; as an abrasive; in filters, etc. Sand and gravel produced in Tennessee in 1919 amounted to 494,538 tons, valued at \$353,937, not all originating within the Tennessee River Basin. Several companies near Knoxville, produced 117,960 tons of sand, in 1919, largely used to make concrete. In the same year 25,230 tons were quarried near Chattanooga.

Gravel is used for concrete, roofing, road metal, railway ballast, etc. Several hundred thousand tons are quarried annually near Camden, Tenn., in the Lower Tennessee River basin. Most of this is shipped to Mississippi for road construction, but large amounts have been used in the past for road metal in Tennessee. Gravel, amounting to 31,720 tons was mined near Knoxville in 1919.

Limestone, when finely crushed or ground is extensively used as flux and is an important ingredient in glass making, this material comprising 18 per cent of glass batches. The large limestone quarries at Russellville, Ala., produce besides dimension stone, 10,000 tons of crushed stone per month, which is used for flux by the iron industries at Sheffield and Florence. Certain iron companies operate their own quarries close to the furnaces where the crushed stone is used as a flux.

The reserves of sand and gravel, and stone suitable for crushing in this region are practically unlimited.

Salt and gypsum.—Salt and gypsum beds are exposed in a belt about 20 miles long, in the valley of the North Fork of the Holston River, in Smythe and Washington Counties, Va. (See Chart IV.) These minerals have been found in quantity only in the shales of the Maccrady formation and are genetically related to the Saltville

fault, which passes northeast and southwest through Saltville. This is the only occurrence of these minerals in commercial quantities known in or near the Tennessee River Basin. The Saltville fault and the Maccrady formation extend southwestward but the structural relations are different, and much prospecting has failed to discover commercial deposits in Tennessee. About 50 wells have been drilled in the vicinity of Saltville, Va., ranging in depth from 200 to 2,280 feet, the average being about 1,000 feet. The brine is raised by electrically operated pumps. Gypsum which is associated with the salt deposits, is used ground as fertilizer and roasted to make plaster of Paris. It is also used to make wall plaster, molds, tiles, surgical bandages, cement, etc. Gypsum is calcined at a plant near North Holston, Va., and an alkali works is in operation at Saltville, which treats the brines, and produces caustic soda, and soda ash, etc., the entire salt production being used for this purpose. The process involves the use of large amounts of carbon dioxide gas, derived from limestone, which is quarried nearby.

Talc and soapstone.—Talc deposits are of two kinds, pure talc mineral (either steatite or a similar mineral called pyrophyllite), and a massive rock composed of talc and quartz, talc-schist, known commercially as soapstone, both of which occur in the mountainous regions of the southern Appalachians. The North Carolina deposits occur as belts associated with marble in the headwaters of the Hiwassee and Little Tennessee Rivers. (See Chart IV.) Talc is used in the manufacture of paper, gas-tips, toilet paper, slate pencils, and heat insulators. The electric furnace is used to make certain talc products at Chattanooga. North Carolina and Georgia talc was formerly used, but now larger quantities are imported for this purpose from China and India. Soapstone is cut into slabs and used for sinks, laboratory tables, switchboards, and heat retainers.

The production of talc in the United States in 1918 was 13,263 short tons, or 59 per cent of the world's production. The table below shows the quantity and value of talc and pyrophyllite produced in North Carolina from 1910 to 1918 inclusive:

	Tons.	Value.		Tons.	Value.
1910.....	3,887	\$69,805	1915.....	1,454	\$21,501
1911.....	3,548	57,101	1916.....	1,787	41,824
1912.....	3,542	63,304	1917.....	2,175	41,766
1913.....	4,676	49,817	1918.....	1,661	72,348
1914.....	1,198	28,413			

New and better deposits of talc may be found by employing scientific methods in future prospecting. A great incentive would doubtless be given production in North Carolina if better and cheaper transportation facilities were available.

Zinc and lead.—The zinc and lead deposits of Tennessee are found in two belts, one along the Clinch and Powell Rivers where lead and zinc minerals are generally intimately associated, and another belt near the Holston River, where zinc minerals predominate, with minor quantities of lead. Zinc ores are abundant in Hancock County (upper Clinch River) but are not extensively worked. (See Chart III.) Ores in residual clays near the surface comprise calamine and smithsonite, zinc silicate, and carbonate, respectively, which occur as lumps in these clays overlying the Knox dolomite. Large masses are also found as crusts on the irregular surface of this formation. Zinc, in the form of sphalerite or zinc sulphide, occurs in fractures, along fault planes, and in brecciated zones near the top and base of the Knox dolomite. Lead, in the form of galenite and cerussite, occurs together with the zinc ores, especially along the Powell River.

Primary zinc produced in the United States in 1919 amounted to 452,272 short tons, largely originating in the Missouri district. Zinc produced in Tennessee in 1919 amounted to 50,363 short tons, valued at \$1,591,225, largely from the Mascot (Holston River) and Embreeville (Nolichucky River) mines, representing about one-tenth of the total production for the United States. Lead produced in Tennessee as a by-product in smelting the zinc ores, amounted to 3,678 short tons, valued at \$42,633. Some lead and zinc are mined in the upper Holston River Basin, in Wythe County, Va.

ROLF A. SCHROEDER,
Assistant Geologist.

APPENDIX D.

INDUSTRIAL SURVEY OF THE TENNESSEE RIVER BASIN FROM KNOXVILLE, TENN., TO RIVERTON, ALA.

[By E. D. Stratton and J. G. Kitchell of the Southern Railway Development Service.]

We have 966 industries now in operation located within 15 miles of the Tennessee River. Many of these industries could use river transportation in handling raw materials and finished products if they were offered regular barge or steamboat service at all seasons of the year. A very large percentage of the industries use hydroelectric current. A great many of the industries are expanding from year to year and will, in our opinion, consume twice as much power in the next 10 years as they are using to-day. This estimate includes new industries that are locating at the rate of 50 or more per annum in territory outlined above.

If additional low-cost hydroelectric power could be developed along the Tennessee River, many new chemical plants could be located in the Tennessee River Basin. Millions of acres of limestone, coking coal, iron ore, also timber suitable for paper pulp, are found along the river and its tributaries.

More than 29 different minerals are found in commercial deposits within 100-mile rail haul of the larger manufacturing cities located on the Tennessee River.

Bauxite.	Graphite.	Quartzite.
Barytes.	Iron ore.	Salt.
Copper.	Kaolin.	Silica.
Clay.	Lead.	Silex.
Coal.	Limestone.	Shale.
Calcite.	Mica.	Slate.
Dolomite.	Marble.	Shale (oil bearing).
Feldspar.	Manganese.	Talc.
Fuller's earth.	Ochre, yellow.	Tripoli.
Fire clay.	Oil, mineral.	Zinc.
Granite.	Phosphate.	

The mussel shell beds of the Tennessee River and its tributaries should be surveyed, and if found in paying quantities, developed. It would not be difficult to interest pearl-button manufacturers in establishing plants at points where these shells could be concentrated.

TRANSPORTATION.

The industries in this territory are building up a very large export trade with the Latin American countries. Freight tonnage of this class may some day move via water routes, through New Orleans. Several coal mines have been opened up within a mile of the Tennessee River. A number of coal and iron ore outcroppings are found along the river which could be handled by water routes if properly developed. A very large tonnage of forest products and agricultural products are now being handled into Knoxville, Lenoir City, Loudon, Dayton, Chattanooga, Riverton, Bridgeport, Decatur, Sheffield, and Florence via boats operating on the Tennessee River and its tributaries. Millions of cords of chestnut wood will move into Decatur, Chattanooga, and Knoxville in the future to be used in the manufacture of tannic acid. The four extract plants now in operation at points named will consume 120,000 cords of this wood per annum.

Thousands of tons of red iron ore were brought into Chattanooga via barge from points on the Tennessee River northeast of Spring City not many years back and used in manufacture of pig iron by the old Citico Furnace.

There is no reason why a heavy tonnage of this ore should not be moved by river to Chattanooga if river transportation is improved and market furnished for the ore.

The Roane Iron Co. have moved thousands of tons of red iron ore from point on Tennessee River just below Seven Islands, east of Kingston, Tenn., to railroad incline at mouth of Caney Creek, near Rockwood, and used in pig-iron furnaces at Rockwood, Tenn. They have handled a trainload of such ore daily during the past 11 months, the water haul being about 35 miles by river. Bauxite, silica, red ore, and brown iron ore are found in large deposits along the Tennessee River north of Chattanooga, which could be brought to Chattanooga via barge or boat if offered regular service at competitive rates.

Men who have tried to develop traffic along the river north of Chattanooga say it can not be done in a satisfactory manner until public-road right of ways are condemned and opened to the river. The farmers owning land along the river try to

charge an exorbitant toll to those who want to reach the river with any quantity of freight.

There is a large deposit of bauxite and iron ore at Hixon, Tenn., within half a mile of the Tennessee River and 4 miles or more from the railroad. This ore could be handled with less trouble by trams to the river than by trucks to the railroads.

Limestone-crushing plants established along the river could supply the farmers with ground limestone for agricultural purposes which would increase yields.

Appended is a list of principal cities in described territory and the number of industries located at each one of them.

SOUTHERN RAILWAY DEVELOPMENT SERVICE.

E. D. STRATTON, *South American Agent.*

J. G. KITCHELL, *Industrial and Immigration Agent.*

CHATTANOOGA, TENN., December 8, 1920.

INDUSTRIAL SURVEY OF CITIES AND TOWNS IN THE TENNESSEE RIVER BASIN.

Industries.		Industries.	
Athens, Tenn.	19	Lenoir City, Tenn.	10
Clinton, Tenn.	9	Newport, Tenn.	7
Cleveland, Tenn.	27	Riverton, Tenn.	3
Chattanooga, Tenn.	362	Rockwood, Tenn.	6
Charleston, Tenn.	6	Stevenson, Ala.	6
Decatur, Ala.	30	Sweetwater, Tenn.	7
Dayton, Tenn.	(¹)	Scottsboro, Ala.	8
Florence, Ala.	37	Sheffield, Ala.	27
Huntsville, Ala.	41	Tusculum, Ala.	10
Knoxville, Tenn.	356		
Loudon, Tenn.	5	Total	966

APPENDIX E.

REPORT ON THE NATURAL RESOURCES OF THAT PORTION OF THE TENNESSEE RIVER BASIN TRAVERSED BY AND IMMEDIATELY TRIBUTARY TO THE CAROLINA, CLINCHFIELD & OHIO RAILWAY.

GENERAL.

Location.—The territory under consideration, which for convenience will be designated the Clinchfield territory, extends from the Cumberland Mountains of Virginia to the Blue Ridge Mountains of North Carolina. The States of Virginia, Tennessee, and North Carolina are crossed in a northerly and southerly direction. The territory includes all or a portion of the following counties: Russell, Wise, and Scott Counties, Va.; Hawkins, Sullivan, Washington, Carter, and Unicoi Counties, Tenn.; Mitchell, Yancey, and Avery Counties, N. C. The total mileage of the railway from Dante, Va., to Altapass, N. C., is 152 miles; the distance by air line is approximately 80 miles. The areas of the counties just mentioned aggregate 2,466 square miles. The population in 1910 was 218,481. The estimated population in 1920 is 300,000.

Water courses.—This territory is drained by the Clinch River in Virginia, the Holston and Nolichucky Rivers in Tennessee, and the Toe River and its tributaries in North Carolina. The Clinchfield Railway enters the Clinch River drainage area at Dante, Va., and strikes the main fork of the Clinch at St. Paul, Va., and follows the course of the Clinch River down to Clinch, Va., then goes through the Clinch Mountain and enters the Holston River drainage area, crossing the North Fork of the Holston River just north of Kingsport, Tenn. It then follows up the South Fork of the Holston River to Hemlock, a distance of about 9 miles. After crossing numerous branches of the South Fork of the Holston and Watauga Rivers, the railroad enters the Nolichucky drainage area at Unicoi, Tenn. It follows North Indian Creek to Erwin; from that point it goes up the Nolichucky to the North Carolina State line; thence it follows the Toe River up to a point near Altapass. At Hunt Dale, N. C., Cane River, which drains a large portion of Yancey County, N. C., enters the Toe. At Kona, N. C., the South Toe, which drains the southeastern portion of Yancey County, enters the Toe. From Kona the river is known as the North Toe and its source is in Avery County, N. C.

RESOURCES.

Power.—The major portion of the power used in this territory is produced from coal. This is due to the fact that in the Cumberland Mountains of Virginia and Kentucky, which form the northern boundary of this territory, are large areas of high-grade

¹ Strawberries.

bituminous coal. In what may be termed the Clinchfield fields alone there are five or six hundred thousand acres of coal land. Several large coal mines are now in operation, but the field has hardly been touched.

In addition to the steam power, or the steam-electric power, there is only one hydroelectric plant now in operation in this territory. One or two plants outside of the territory are furnishing electricity to some of the coal operations within the territory. The hydroelectric plant in operation is the Tennessee Eastern Electric Co., headquarters at Johnson City, Tenn. The plant is located on the Nolichucky River west of Erwin, Tenn. This plant has a capacity of around 5,000 kilowatts, but this capacity can be practically doubled by increasing the height of the dam. Electricity from this plant is supplied to Greeneville, Jonesboro, Johnson City, and Erwin, Tenn.

From an estimate of the water possibilities in this territory which are yet undeveloped, there is a total of 65,070 horsepower as follows:

Clinch River (Clinchport to Indian Creek): Distance, 110 miles; drainage area, 550 square miles; horsepower, 10,125.

Nolichucky, Toe, and branches (Greeneville to head): Distance, 171 miles; drainage area, 1,771 square miles; horsepower, 48,605.

South Fork of Holston (mouth to Watauga River): Distance, 18 miles; drainage area, 1,940 square miles; horsepower, 6,340.

Totals: Distance, 299 miles; drainage area, 4,261 square miles; horsepower, 65,070.

The theoretical horsepower calculated for this area would be considerably greater than that shown above. These estimates were made as showing what could probably be developed taking into consideration the practical conditions involved, such as the location of railroads and excessive construction costs. With proper development of these water powers the maximum horsepower should be made available by reason of the fact that such a large quantity of high-grade bituminous coal is located near by, which could be used in auxiliary steam plants.

Again, the amount of power can be greatly increased by building proper storage dams. Such storage dams could be built, it is believed, on the headwaters of the Clinch, North Toe, South Toe, and Cane Rivers, and probably on the headwaters of the Holston River. These storage dams should be so constructed and located that they would be of value in controlling floods or preventing the possibility of floods.

Timber.—This entire territory is in what is known as the Southern Appalachian Forest. Government reports have shown that this was one of the greatest hardwood sections of the country. Of course, a considerable amount of the timber has been cut, but from a careful estimate we believe that the standing timber in this territory at the present time will cut over one and one-half billion feet of merchantable lumber. In Virginia and Tennessee are yet found some of the finest of white oak and poplar, while in North Carolina is located the great chestnut and spruce section. The timber resources in this territory have played a very prominent part in the development of the territory and no doubt will continue to do so.

Minerals.—It is believed that the mineral resources will be the greatest single factor in the future development of this territory. The statement below gives only such minerals that it is believed will be found in commercial quantities, and so located that they may be economically mined.

Asbestos.—The asbestos deposits so far investigated are located in Mitchell and Yancey Counties, N. C. This mineral is of a short-fibered amphibole type. One large deposit is found near Micaville, N. C. There are other deposits in this immediate territory as well as deposits near Toecane and Bakersville in Mitchell County, N. C. This material should be suitable for roofing and in certain fireproofing products. On account of its short fiber it is not suitable for spinning. It should find uses in other products where heat resistance is desired.

Several carloads of this short fiber asbestos have been shipped and ground up for the roofing trade, but at the present time there is no movement on this material. The market is too far away. It will probably be necessary to either establish grinding plants and prepare the material near the mines, or await the coming of roofing and other plants into this territory before this material will find a ready market.

Barite.—There are several deposits of barytes in this territory, but one that promises to be of great commercial value is in Unicoi County, Tenn. This material has been shipped but not regularly on account of transportation facilities. The deposit near Pactolus, Tenn., is of the highest quality but is not economically mined. Both of these deposits are well worth considering in the future development of this territory because of other deposits nearby in the South.

Bauxite.—This material is not directly on the Clinchfield Railway. It is found at Keenberg, near Elizabethton, Carter County, Tenn., about 13 miles from Johnson City. The Merrimac Chemical Co., Boston, Mass., owns one deposit and is now mining

bauxite. There is another deposit nearby which is owned by the Southern Minerals Corporation. Considerable prospecting has been done but no ore has yet been shipped.

Associated with the bauxite there are large quantities of clays called bauxitic clays. These clays are from white to buff in color and possess great plasticity. These clays should be worth consideration as a source of raw materials for refractory products.

Chromite.—There is a deposit of chromite in Yancey County, N. C., about 5 miles from Green Mountain. Several carloads of this material were mined and shipped during the war and the deposit was again opened up this year. The material runs very high in chromic oxide.

Dolomite.—A deposit of practically pure dolomite is found near Toecane, N. C. There seems to be a very large quantity of this material. It is a white granular stone and takes a very beautiful polish. It analyzes 54.87 per cent calcium carbonate and 44.25 per cent magnesium carbonate. There has been none of this material mined up to the present time. It is exposed in the cut made by the railroad and extends back probably a mile through the ridges.

Feldspar.—There has been greater activity in the mining and shipping of feldspar in our territory than in any other of our minerals. Our feldspars are found in Mitchell and Yancey Counties, N. C., and are shipped from practically all of the stations from Green Mountain to Spruce Pine, inclusive, as well as on the Black Mountain Railway up to Burnsville, inclusive. Most of the feldspar that has been shipped is of the potash variety, but there is some soda feldspar in the territory. According to our records the feldspar producers in the Clinchfield territory will ship from 65,000 to 75,000 tons of spar during 1920. In view of the opening up of some new mines and the construction of new railroad facilities, the production should be considerably greater for 1921.

Iron ore.—With the exception of the Cranberry Furnace in Johnson City, which uses magnetic iron ore from Avery County, N. C., there are no furnaces in the Clinchfield territory and therefore our iron ore has not been developed. The magnetic iron ore deposits of Avery County, which are so well known, extend over into Mitchell County and are therefore accessible from points on the Clinchfield. Brown iron ore is found in what is believed to be commercial quantities in Unicoi County, near Chestoa, Tenn., and near Unicoi, Tenn. Similar ore is also found in Scott County, near Fort Blackmore, Va. There is also another deposit of ore near Fordtown, Tenn. Owing to the distance of furnaces using this class of ore, these deposits have never been developed, but they are of sufficient importance to be of value in the future development of this territory, particularly so if iron furnaces are established nearby.

Kaolin.—In the same territory and closely associated with the feldspar are found large deposits of kaolin. This is simply decomposed pegmatite, but is of such quality as to be in great demand by the pottery and other ceramic industries. There are four kaolin washing plants located at Spruce Pine, Penland, Micaville, and Intermont, N. C. A typical analysis of this kaolin shows that it runs about 40 per cent alumina. According to the records of the railroad the four kaolin plants will ship from 350 to 375 carloads of kaolin during 1920. There are other deposits of kaolin yet undeveloped, one in particular which has been very thoroughly prospected, and no doubt will be opened up in the near future.

Limestone.—There are massive beds of limestone in this territory all the way from St. Paul, Va., to Erwin, Tenn. The high calcium beds are found in Scott County, Va. The Clinchfield Portland Cement Corporation, Kingsport, Tenn., is the largest user of high calcium stone. There are several deposits of limestone between Johnson City and Erwin, but they contain more or less magnesium. This is good clean stone, and should be suitable for any purpose where the magnesium content is not objectionable. It is believed that there is ample limestone and of suitable quality to take care of the requirements as the result of the future development in this territory.

Manganese.—There are several manganese deposits in the Clinchfield territory, but the only one along the Clinchfield that has been operated is near Unicoi, Tenn. This was operated during the war and several carloads of the material were shipped. There are other deposits in the same general territory in the vicinity of Elizabethton, Tenn. Several mines in that section were operated during the war. There has been no activity since the armistice. The deposits, however, should be of great value in the future development of this section. The ore is of high quality and seems to be in considerable quantity.

Marble.—There are several marble beds in this territory, only one of which is pure white marble. This is located at Intermont, N. C., in Mitchell County. Beds of marble of dull and variegated colors are found in the vicinity of Erwin, Tenn., and also around Speers Ferry, Va. There has been no effort made to develop any of these marble deposits. A mottled white and gray marble of beautiful polish is located near Linville Falls, N. C., just southeast of Altapass.

Mica.—Mitchell and Yancey Counties, N. C., have long been noted as being an important mica-producing section. The Muscovite variety of mica is found from Green Mountain to Altapass, N. C., and also for a great distance east and west of the railway. The mining of this commodity is an important industry in this part of North Carolina, and the product is in great demand because of its quality. There are several mica plants in the territory. Some of them cut mica and others grind scrap mica.

Mica schist.—There are large deposits of what is known as black mica schist and white mica schist. These materials promise to be of great value as substitutes in some instances for ground mica. A plant at Spruce Pine, N. C., is now grinding black mica schist. Their ground product is used by the roofing people as a coating for composition roofing. It is believed that a good market will be found for the white mica schist when it is properly prepared.

Ochres.—There are several beds of ochre in the territory, but the principal deposit is near Poplar, N. C. This is a yellow ochre, and from tests made it has value as a paint material. The deposit is yet undeveloped.

Phosphate.—There is no phosphate rock directly on the Clinchfield, but near Mountain City, Johnson County, Tenn., there are several deposits of this material. An analysis shows that it will run better than 76 per cent bone phosphate of lime. These beds are of interest to this territory, as it is believed that they are of sufficient importance to be of value in the future development of this section. The Tennessee Geological Survey has made a very careful investigation and report on these deposits.

Quartzite.—There are massive beds of gray quartzite along the Nolichucky River between Unaka Springs, Tenn., and Poplar, N. C. This is known as the Erwin quartzite. Another deposit of quartzite is found at Linville Falls, N. C., just outside of the territory under consideration. This Linville Falls quartzite is a white material of very high silica content. There is an unlimited quantity of it. This quartzite should be especially suitable for silica brick.

Salt.—The large and important salt measures of Washington and Smyth Counties, Va., in the Saltville district, are available to the industries on the Clinchfield. The importance of this is a matter of great moment in connection with the electrochemical development in the Clinchfield territory.

The geological formations that carry the salt at Saltville cross the Clinchfield near Waycross, Tenn., just 6 miles north of Kingsport. In view of the identical geological characteristics of the country at Saltville and at Waycross it seems reasonable to expect to find the immense beds of salt and gypsum at Waycross which occur farther east.

Shale.—Shales suitable for the manufacture of brick and cement occur in large amounts in eastern Tennessee and southwestern Virginia. That part of the Clinchfield between Kingsport and Erwin is especially rich in good shales. The excellence of the shale showing at Kingsport is amply shown by its extensive use in the manufacture of cement, brick, and tile at that point. Recent tests have shown that this shale is suitable for the manufacture of acid-proof brick. It should be mentioned in this discussion that the bauxitic clays and the siliceous minerals found on the line at other points permit the manufacture of clay ware of almost any desired composition.

Silica sand.—In the Clinch Mountain at Kermit, Va., there is a bed of massive sandstone many hundred feet thick and extending through the country for a great distance. In composition this stone is a fine-grained material composed of almost pure silica, and its value as a source of silica is readily seen from the analysis.

Per cent.

Silica (unwashed).....	99.64
Alumina (unwashed).....	.25
Ferric oxide (unwashed).....	.10

The Pennsylvania Glass Sand Co., of Lewistown, Pa., have acquired a large acreage of the sand at Kermit and have established a grinding and washing plant. They will begin shipping sand about the first of 1921.

Slate.—Slate in considerable amounts is to be had both at Unaka Springs and at Kingsport, Tenn. While this important commodity has been worked only slightly, and then for local consumption, it exists in large amounts and appears to have a good cleavage and to be free from joints. This slate gives promise of being of value for table tops, sinks, etc. Some of these slate deposits should furnish ground slate to surface roofing.

Soapstone.—The igneous rocks tributary to the Clinchfield carry numerous beds of soapstone. This material is readily sawed and being free from fluxing constituents, is resistive to heat. The soapstone found on the Clinchfield is also suitable for the construction of sinks, tubs, and switchboards. Talc is also found, and is in demand for the manufacture of molded goods and gas-burner tips of various kinds. There is no one actively engaged in mining soapstone or talc at the present time.

Zinc.—At Embreeville, Tenn., about 6 miles west of Erwin, are the only zinc mines in operation in the Clinchfield territory. The deposits at Embreeville are well known. Both smithsonite and calamine are mined. There are deposits of sphalerite at Fall Branch and Arcadia, about 9 miles west and east of Kingsport, respectively. Many years ago the Fall Branch deposit was operated but no modern equipment has ever been installed so that the mine could be economically worked.

TRANSPORTATION FACILITIES.

The Clinchfield territory has good transportation facilities. The connection on the north at Elkhorn City, Ky., is the Chesapeake & Ohio Railway, whose lines extend into Cincinnati and Chicago as well as into the upper Ohio Valley. At St. Paul, Va., the Norfolk & Western Railroad furnishes an outlet through Bluefield to the east and north and to the west through Norton, Va.; at Speers Ferry, Va., the Southern Railway's Appalachian division serves a large area in southwest Virginia and Kentucky; at Johnson City, Tenn., is the main line of the Southern Railway between Washington and Chattanooga; while from Altapass, the southern portion of the territory under consideration, the C. C. & O. R. R. has connections with the Southern Railway at Marion, Seaboard Air Line at Bostic, and the Southern, C. & W. C. and P. & N. Railways at Spartanburg, S. C.

INDUSTRIAL DEVELOPMENT.

Prior to the construction of this Clinchfield Railway there were very few industries in the Clinchfield territory. A few sawmills and woodworking establishments were practically the only industrial development in this section. The Clinchfield Railway was put in operation from Dante, Va., to Altapass, N. C., about 1908, but the real industrial development did not begin until about 1912 or 1913. Since that time this development has been very rapidly increasing, as will be noted from the several large industrial plants noted below.

Dante, Va.—The Clinchfield Coal Corporation are the largest coal shippers on the Clinchfield. They own over 300,000 acres of coal land and are shipping now at the rate of from two to two and a half million tons annually.

Clinchfield, Va.—The International Coal Products Corporation is a coal by-products plant. It is a very large concern and its finished products include carbocoal and coal-tar products.

St. Paul, Va.—The Clinch River Extract Corporation manufactures tanning extracts from chestnut wood and bark.

Kermit, Va.—The Pennsylvania Glass Sand Co. have about completed their plant to grind and wash silica sand for the glass industries.

Kingsport, Tenn.—The Kingsport Extract Corporation and the Kingsport Tannery are subsidiary companies of the Grant Leather Corporation. The last-named corporation is affiliated with the Simons Hardware Co., of St. Louis. They manufacture all kinds of leather products with particular attention to harness, saddlery, etc.

The Meade Fibre Co. makes pulp for the Meade Paper Co., of Dayton, Ohio.

The Clinchfield Portland Cement Corporation is one of the oldest and largest of the industries in Kingsport. It has a capacity of 2,500 barrels of cement daily. It secures its limestone from Speers Ferry and Gate City, Va., and its shale from a hill near the plant.

The Kingsport Brick Corporation has a capacity of 150,000 brick per day. It uses shale near the plant and manufactures common red shale brick, face brick, rugs, textiles, etc.

The Corning Glass Works, a branch of the Corning Glass Works, of Corning, N. Y., manufactures Pyrex ware, using the silica sand at Kermit, Va.

The Tennessee Eastman Corporation, a subsidiary of the Eastman Kodak Co., of Rochester, N. Y., is putting into operation a wood alcohol plant. They have other plants for development and expect to manufacture several of their products at Kingsport.

The Union Dye & Chemical Corporation manufactures aniline oils and other chemicals.

The Kingsport Hosiery Mills has a capacity of 2,000 dozen pairs of hose per day. The Kingsport Utilities (Inc.) operates a steam-electric power plant with a capacity of about 15,000 horsepower.

Johnson City, Tenn.—The Cranberry Furnace Co. manufactures high-grade pig iron from the magnetic iron ore mined in Avery County, N. C.

Rollin Chemical Corporation manufactures sodium sulphate, muriatic acids, and other chemical products.

The M-B Chemical Corporation manufactures dyes.

The Johnson City Shale Brick Corporation will be in operation in a very short while and will manufacture high-grade brick from shale near the plant.

There are several woodworking plants, including chair factories, furniture factories, flooring, box, and textile supplies. The Johnson City mills manufacture hosiery, and the Tennessee silk mills manufacture silk products.

Erwin, Tenn.—The Southern Potteries (Inc.) manufacture high-grade dinner sets and other ware. They use kaolin and feldspar from the near-by mines of North Carolina.

The Southern Electrical Porcelain Corporation manufactures electrical porcelain products, using the clays and feldspars near-by.

The Clinchfield Products Corporation and the Erwin Spar Corporation grind feldspar for the general trade.

A. P. Villa & Bros. are spinners of raw silk.

North Carolina.—The Harris Clay Co. has four kaolin plants which are at Inter-mont, Micaville, Spruce Pine, and Penland, N. C. There are several mica mines grinding and cutting mica for the general trade.

SUMMARY.

It is to be noted that the industries already located in the Clinchfield territory are diversified. This tends to make the development not only sound and permanent but assures a progressive and rapid growth. The two important factors in the future development of this section will undoubtedly be the development of the water powers and the various mineral resources. The proper investigation and tests of the minerals should prove their commercial importance and put the opportunity before manufacturers and others in need of raw materials. A few of the problems of this development work that should receive the immediate attention of those interested are outlined below.

Power.—A thorough investigation and estimate should be made of all of the prospective water powers on the Clinch, Holston, Nolichucky, and Toe Rivers, as well as their tributaries, and the result of this investigation should be considered in conjunction with the possibility for supplementing this power by the use of steam-electric plants as auxiliaries. Such an investigation would not only indicate the amount of power that might be depended upon for the development of our minerals and other resources, but might also be an important feature in connection with the possibility of the electrification of the railroad. In connection with this power question, the investigation should not only include the power possibilities directly within the territory, but should also consider such powers as may be developed on the Linville River, which is just southeast of Altapass, N. C., and should also consider the power that is already developed on the New River in Virginia, which power is now being transmitted to such points in the coal fields as Dante and Clinchfield, Va. This last-named power is owned by the Appalachian Power Co., Bluefield, W. Va.

Refractories.—With the chemical and semichemical industries that have already been established and others that will likely be established, the subject of refractories is already a vital question. Thorough tests should be made of our clays, or our quartzite, and other silica and aluminum minerals with the view of manufacturing the necessary refractories in this territory.

Electrochemicals.—With our iron ore, manganese, chrome, and silica there should be great possibilities in the development of electrochemical plants and the natural resources of this territory should be thoroughly investigated with this in view.

The above are only a few of the important problems in the development of this section, but the foregoing statement of the natural resources will suggest other problems of economic importance. The development of these resources will not only benefit the immediate section but will benefit the whole country, and therefore it is believed that the departments of our Government should make certain surveys so as to bring out fully and accurately the real value and importance of these resources and suggest in what manner they should be developed. It is believed that a survey of the water power is one of the first that should be undertaken. It is likely that after such a survey is made individuals and corporations interested in the mineral deposits will be glad to assist in making the necessary investigations and tests so that the important minerals will be properly developed.

Respectfully submitted.

D. C. Boy,
*Industrial Agent Carolina, Clinchfield & Ohio Railway,
Johnson City, Tenn.*

DECEMBER 4, 1920.

APPENDIX F.

[Letter of Dr. T. Poole Maynard, Geological and Industrial Engineering.]

ATLANTA, GA., December 13, 1920.

DEAR SIR: In compliance with your request, I am briefly outlining the industries made possible by the development of water transportation and water power in the valley of the Tennessee.

You are well aware that the development of the fertilizer industry in the South is in its infancy. Our most desirable source of nitrogen for agriculture is derived from air by the application of electricity, such as the cyanamid and other processes.

Phosphoric acid is now being obtained by volatilization in the electric furnace at Anniston, Ala. There is every possibility that our cheapest source of phosphoric acid in the future will be that made available by the application of cheap hydroelectric power.

You are well aware that the three essential plant foods are potash, phosphoric acid, and ammonia. The phosphate deposits of the eastern United States are located in Tennessee and Florida. It is not generally recognized, but nevertheless true, that the only potash deposits which have real commercial possibilities in the United States are the potash slates of north Georgia. The development of the potash industry to meet the requirements of the South would require an expenditure of \$100,000,000 and would utilize as much 24-hour power as 100 such plants as the Dixie Portland Cement Co. now uses at Richard City, Tenn.

The aluminum industry is dependent upon cheap hydroelectric power and the ore of alumina, namely, bauxite. This industry has been controlled largely by the Aluminum Co. of America, on account of patents and the control of most of the commercial deposits. This is no longer true on account of the expiration of the patents and the fact that methods have been devised for the concentration of low-grade ores of alumina to high-grade ores, by simple methods of concentration. This makes available millions of tons of bauxite not previously considered of any commercial importance. The alumina industry is bound to remain in the South, and the extent of the growth of the industry seems to be limited to the cost of production, based on the availability of hydroelectric power and raw materials.

The manufacture of abrasives is another industry dependent upon hydroelectric power. At this time the clays and bauxites used in the manufacture of abrasives are shipped from Georgia, Alabama, and Tennessee, to Niagara Falls on account of the availability of hydroelectric power at that point. High-grade alloy steels require abrasives for cutting and polishing and the abrasive industry is one that will materially enlarge.

There are numberless smaller industries dependent upon hydroelectric power for development in the Tennessee Valley, and I am confident that you will find by making an intensive investigation of the resources of the South many possibilities for the utilization of hydroelectric power other than those mentioned.

Respectfully yours,

T. POOLE MAYNARD, Ph. D.,
Geological and Industrial Engineering.

PARTIAL SURVEY OF TENNESSEE RIVER AND TRIBUTARIES.

UNITED STATES ENGINEER OFFICE,
Chattanooga, Tenn., March 15, 1922.

From: The District Engineer.

To: The Chief of Engineers, United States Army
(Through the Division Engineer.)

Subject: Report on progress of survey of Tennessee River to March 1, 1922.

1. The river and harbor act of June 5, 1920, contains an item for a preliminary examination and survey of the Tennessee River and tributaries in North Carolina, Tennessee, Alabama, and Kentucky.

The duty of making this preliminary examination and survey was assigned to this office and under date of January 15, 1921, a report was forwarded through the regular channels to the Chief of Engineers.

2. In this report it was recommended that a survey be made of the Tennessee River and its tributaries for the purpose of formulating a plan of future development of navigation on these streams and that in making this survey there be included studies of all present or potential hydroelectric developments, the mineral and industrial resources of this basin, etc., as may have appreciable influence on any project for river improvement that may finally be recommended or as may be necessary to protect the interests of the Government when issuing permits in this region for proposed developments by private parties. It was estimated that the cost of a survey such as that recommended would be something over \$500,000. At the time that the report was reviewed by the Chief of Engineers no such sum was available for this purpose and on April 23, 1921, the sum of \$20,000 was allotted to this office for the purpose of making such studies along the line recommended as would be possible with this amount.

3. It was evident that with this allotment only a very small fraction of the work recommended in the preliminary report could be undertaken during the ensuing fiscal year, the period to be covered by this sum, and after careful consideration of the problem it was decided to divide the work undertaken into two classes. This division was based on a recognition of the fact that the survey is to be primarily a study of the entire Tennessee basin, an area of about 40,000 square miles, with a view to formulating one single comprehensive plan for the final development throughout this area of all its possibilities for river navigation, this plan to be put into effect progressively as the growth of actual navigation in the future justified further development of this kind. This region has striking possibilities for further development of hydroelectric power both on the Tennessee River itself and on many of its tributaries. The fundamental problems connected with the use of water for this purpose are inextricably involved with those pertaining to the use of the same water for navigation. Therefore it seemed clear that one part of the funds available should be used in collecting data needed for the study of these common interests since there was already on file in this office much valuable information bearing directly on the needs of navigation in so far as this subject could be considered independently of power development.

4. On the other hand, it was realized that there is a widespread interest throughout the country both in water transportation and in hydroelectric development, and the collection of data pertaining to the entire basin would be only of academic interest until such data could be applied to some specific section to show in a concrete instance what benefits will actually flow from this method of studying one complete and self-contained river basin. Since theoretically, and practically as well, each individual development in the basin has some more or less direct bearing on every other there, it is, strictly speaking, impossible to solve one problem completely until all pertinent data for the entire basin are at hand. In spite of this fact it seemed highly desirable to present at this time in as complete a form as possible one individual study both as an example of what may be expected in other cases and also to permit at the earliest possible date the actual construction of a work of recognized value both to

navigation and to the interests dependent upon hydroelectric power. It was therefore decided to seek the locality where the most was to be expected from the data that could be promptly obtained, though these could not be made complete with available funds, and to expend on the acquisition and study of these data as much of the \$20,000 as could be spared from the more general work above mentioned.

5. Considering first the collection of those data which in general have to do with the Tennessee River Basin as a whole, these may be classified under the following heads as data referring to—

- (a) Stream flow (Appendix A).
- (b) Flood profiles (Appendix B).
- (c) Level system (Appendix C).
- (d) Maps (Appendix D).
- (e) Silt deposits in Tennessee River (Appendix E).

Funds were spent in the collection of data coming under these designations. In addition, avenues of possible investigation were constantly opening up which gave promise of results of greatest interest and value, but from which, due to lack of available funds, we were obliged to turn aside. A few of those showing the most promise are mentioned below. The results obtained from general investigations may be briefly summarized as follows:¹

Stream flow.—The whole proposed study rests primarily on a full knowledge of the flow of water in the various streams. Data relative to gauge heights, discharge, low and high water levels, floods, etc., give the starting point of all further investigations. A large amount of information of this character for the Tennessee River Basin has accumulated during the last 50 years. This had to be assembled in a readily accessible form, gaps located and if possible filled in, errors located and corrected, and adequate means devised for keeping these records up to date for an indefinite length of time. In order to make the small sum which could be spared for this purpose from the available allotment go as far as possible, this matter was taken up with the United States Geological Survey and the Geological Survey of the State of Tennessee, and a cooperative agreement was entered into whereby this office furnished \$4,000 and the other organizations furnished together \$6,000 for stream-flow studies for the ensuing year. In this way this office will for \$4,000 obtain \$10,000 worth of information of fundamental importance to its work. Some financial contributions for this work from power companies interested in this matter have been made through the Geological Survey. In Appendix A is given more in detail a report of the activities along this line up to January 1, 1922.

Flood profiles.—The city of Chattanooga has a well-defined flood problem, and some other cities, towns, and farm lands are occasionally damaged, particularly at the highest stages. Generally speaking, however, property damage due to high water is not as great in this basin as it is in some others, and consequently no accurate records have been kept from which may be derived the complete profile of any particular stream at flood stages of different heights. Such profiles are, however, necessary not only in connection with studies of high head plants with large storage, but more particularly for lower head dams on navigable rivers where the interests of both navigation and power development must be considered simultaneously. In

¹ Illustrations not printed.

this latter case two different problems appear. The first has to do with the extent to which a proposed dam will increase flood heights above it, thus increasing the amount of flood damage and claims for such damage which must be charged to the cost of the project. The second has to do with the extent to which a power-navigation dam may be drowned out during a flood with corresponding loss of head for power, and therefore decrease in the value of the project from the power viewpoint.

To handle these questions properly it is necessary to know, first, the height reached by the flood under consideration at every point along the river; second, the volume of discharge at the maximum stage; and, third, the back water curve or flood heights which would have been attained above any proposed dam if that dam had been in existence at the time of the flood under consideration. Much effort and some money has been spent during the last eight months in the preparation of flood profiles, with the result that these profiles have been drawn for the Tennessee River from Knoxville to Hales Bar. From Knoxville to Kingston these are probably sufficiently accurate for the purposes of this survey. Between Kingston and Chattanooga progress has been made beyond anything available before, but it is expected that here these profiles will be improved when further map work is done in this section. From Chattanooga to Hales Bar the profiles are very accurate. The collection of flood profile data will have to continue as long as the survey lasts. Appendix B gives plates showing these profiles and backwater curves above the Hales Bar Dam. With the information required for proper consideration of flood damage claims, the height of the water above and below the dam is readily obtained. This gives the head at any stages and permits the effect of high water on power production to be intelligently discussed.

Level system.—In the preliminary report on this survey mention was made of the fact that a number of surveys have been made in this territory during the last 50 years and that in the course of making these surveys several level systems have been introduced which, in general, are not thoroughly consistent with each other. Bench marks, ample for present purposes, exist along the Tennessee River above Chattanooga as a result of the work done in the surveys of 1891 and 1909 and considerable work was done toward reconciling these with the latest and most accurate adjustment of elevations, that of the United States Coast and Geodetic Survey made in 1912. Those in the first 50 miles or so below Knoxville were made available and a moderate amount of additional work only is needed down to Chattanooga. Mean sea level datum as established by the United States Coast and Geodetic Survey is used in this work. Appendix C gives much interesting and valuable detail on this subject.

*Maps.*¹—As stated in the preliminary report, existing maps of this section are either on too small a scale or do not cover enough territory for the purposes of the present survey. Having decided upon the section which was to be made the subject of special study at this time, additional maps of this region were needed, and this required some attention to the more general subject of how all maps of this kind were to be made.

To reduce the drain on the small available allotment, careful consideration was given, among other things, to the use of aerial photog-

raphy as an aid in mapping, and after consultation with representatives of the Air Service of the Army an agreement was reached whereby over 1,000 photographs were taken of the Tennessee River and the territory immediately adjacent to it from Knoxville to Chattanooga. Appendix D gives in detail a report on this subject. Briefly summarized, it may be stated that experience has demonstrated the value in map making of aerial photographs, properly taken over level, or practically level, ground. While most of the topography adjacent to the rivers in this basin is not practically level, it is a fact that the slope of the Tennessee itself is nowhere throughout its length sufficient to cause any measurable distortion in an aerial photograph, and hence as far as aerial photography is concerned the water surface of the river may be considered a level surface. Furthermore, no practical power-navigation project along this river could possibly affect lands lying higher than 100 feet above this water surface, and here again distortion due to this difference of elevation on properly taken photographs is too small to be of material importance in this survey. It might be well to state here that when it becomes possible to continue this survey on the tributaries of the Tennessee it is proposed to employ aerial photography in connection with the map making done there. Steeper river slopes will be found there, and it will probably be necessary to take topography to 200 or even 300 feet above the water surface in some cases. In such an event there is more chance that distortion from this cause may become apparent, but it is expected that no material errors will be introduced. However, this point will be borne in mind, and any errors due to this cause will be corrected in the finished maps by checks made by field parties engaged in locating contours.

Silt deposit.—In former studies of power-navigation projects on the Tennessee River it has been assumed that all land lying below the water line of the proposed pools, and consequently overflowed at all times, was permanently withdrawn from agricultural use. In the case of the pool formed by the Hales Bar Dam such overflowed lands are being built up very rapidly by deposits of silt. Much of this is again under cultivation, and it seems probable that at no very distant date practically all will become rich farm land. Such deposit is sure to occur in any pool formed on the Tennessee River, and it is hoped that a realization of this fact will materially reduce the amount claimed as damage to overflowed land. This subject is discussed in more detail in Appendix E.

6. Of the many lines of possible investigation of general interest which could have been followed with propriety in a survey of this kind, except for the lack of available funds, mention may be made of only a few. For instance, a superpower study for this region is suggested by the fact that during the past year such a study was made under the auspices of the United States Geological Survey for the region between Boston and Washington. The territory included in this region is thickly settled with an extensive development along industrial lines and its power needs are now served by a multitude of power-generating plants. These studies seem to indicate very clearly that by combining these numerous plants into one superpower system a marked increase in efficiency can be obtained and at the same time a very appreciable reduction in the unit cost of the power generated. This seems to be entirely feasible from an engineering

standpoint, but the financial and legal aspects appear to present difficulties as yet unsurmounted, while the greatest problem of all may well be that of actually persuading tens of thousands of producers and users of power to change from the existing system with which all are familiar to one which at the outset will be to most of these people something new and untried and therefore to be adopted only with much caution and deliberation.

7. During the past year there also appeared War Department Document No. 1039 on the power situation during the war. Among other sections of this report was one devoted to the electric power problems in the Southern States. For convenience in reference four pages (235 to 238, inclusive) of this section giving a summary are extracted and included in this report in Appendix F. In this report it is stated that "in the interests of economy, reliability, and conservation, isolated plant generation should be discontinued and central power substituted." The area included in the "Southern States" is that of Alabama, Georgia, Tennessee, North Carolina, and South Carolina, and is separated from the Boston-Washington region only by the State of Virginia. Of the hydroelectric power generated in these States all that which comes from stations outside the Tennessee basin is dependent for its water supply on the drainage areas lying on the southeastern slopes of the Appalachian Mountains. The entire northwestern slope of these mountains in these States drains into the Tennessee Basin except for a relatively small portion in north central Tennessee drained by the Cumberland River. Definite figures are not yet available to show the total amount of actual and potential hydroelectric power available on each of these two slopes. Indications are, however, that at least one-half of the total of such power to be expected from these States will be found to come eventually from the basin of the Tennessee River. Moreover, the Tennessee Basin extends into each of these five Southern States, as well as into Virginia, and this suggests the thought that the shortest and most economical superpower line would most naturally fall in this basin and, if extended into that part of the basin lying in Virginia, would form the most logical route for future connection with the Washington-Boston system. It would also be in the near vicinity of the drainage basins of the Cumberland and the Kanawha and other large drainage basins of Kentucky and West Virginia. It could thus become eventually the principal power artery for much, if not all, the hydroelectric power producing region between the Ohio River and the Atlantic and Gulf coasts. Plate XV (which also appeared in the preliminary report on the survey of the Tennessee River as Chart V) shows the electric-power systems now in existence in the basin of the Tennessee River. It will be noted that in addition to four isolated systems in the northern part of the basin there is, in the central part, a well-developed system extending beyond the basin to Nashville on the north and to the south connecting with the lines in Georgia. Through this system connection is made with the Muscle Shoals region and with Huntsville and vicinity. Also, though not shown on this plate, the Georgia lines furnish a connection with those electric power systems now serving South and North Carolina.

8. A very interesting fact, which perhaps is not widely known, is that the meteorological conditions on the northwestern and south-

eastern slopes of the Appalachian Mountains in this region are almost wholly independent of each other; that is, rain-bearing storms which visit one slope have, as a rule, but little effect on the other, and one slope may suffer from drought while but a short distance away over the divide rainfall conditions and consequent water supply may be entirely normal or better than normal. Such, for instance, was the state of affairs during the fall of 1921. During this year there was a drought on the southeastern slope, which reduced the amount of hydroelectric power available below the amount demanded in that region. In the Tennessee Basin immediately adjacent, however, conditions were normal and it was found possible to send from this basin, over the existing transmission lines above mentioned enough hydroelectric power to supply a large part of the existing deficiency. It is also true that some power was sent from the steam electric power station at Muscle Shoals in the Tennessee Basin. This draws attention to the one important fact which has yet to be mentioned and that is that in the Tennessee Basin are found coal reserves containing several billion tons of coal as yet to be mined, which presumably would be most useful for the steam auxiliaries which would probably be needed eventually for the complete superpower system. This coal is so distributed that steam plants located near the mines would also be very advantageously placed with respect to the hydroelectric system.

9. It has been found, when talking this subject to engineers in close touch with existing hydroelectric power conditions, that they are but moderately interested in the actual development of the large quantities of hydroelectric power which seem to lie within reasonable limits in this section. The cause of this attitude is the fact that there is no point in developing power for which there is no present or immediately prospective market. This justifies the laying of emphasis on the fact that in this survey of the Tennessee Basin it is proposed, as funds are available, to include studies of the industrial situation, present and prospective, which is of primary importance as forming the foundation of water-borne commerce as well as a market for surplus hydroelectric power. Once we have at hand the essential facts relating to present and future possibilities for river-borne commerce, industrial development, and hydroelectric development (with steam auxiliaries), it would seem to be reasonable to expect that general lines could be laid down for the simultaneous development of these three interdependent subjects which would be of marked value to the public as a whole and to each individual who might desire to participate in this matter.

10. Finally, the fact that present industrial development in this region is small as compared with that in the Boston-Washington region is, from one point of view, an advantage instead of a disadvantage. In the Boston-Washington region it is established that a superpower system would be a distinct gain in both efficiency and economy. On the other hand, industrial development in this region has already proceeded so far along very different lines that it may well be that such a new system will never come into general use there. In the Southern States industrial development is, comparatively speaking, just beginning, and if future growth is properly directed the superpower system recommended in War Department Document

No. 1039 should come well within the limits of possibility at no very distant date. It is true that the present survey of the Tennessee Basin covers only a part of these Southern States, but the part which it does cover is from the power point of view the core of the entire region, and what is done here may well prove to be the backbone of all future development.

11. A rather more special case, though one of general interest, is that of the French Broad River. This river above Asheville, N. C., has a drainage area of 1,000 square miles, and a high head dam just above that city would form a reservoir or lake with a superficial area of about 50 square miles. Water from such a reservoir would have to fall a vertical distance of at least 1,600 feet in getting to the foot of Muscle Shoals, and there seems to be good reason to believe that much, if not most, of this head could be used to advantage in the development of power if the matter could only be properly studied. It happens also that the region in the neighborhood of Asheville is well known to and highly valued by tourists, and the addition of a lake of 50 square miles area to the other attractions which now draw visitors to this section is no small consideration in itself. In fact, this consideration is so important that the residents of that section have seriously discussed the proposal to build this dam and form this lake simply for its scenic effect and without any thought to its power possibilities. This instance is mentioned both because of its potential value and also as an example of the unexpected features which even very casual study brings to light, adding importance to some projects from quite novel sources, which in such a case as this may conceivably make possible valuable developments that otherwise might fail.

12. Another very tempting line of investigation was opened by the correspondence between this office and the engineer office at Florence, Ala., but due to lack of sufficient funds no material progress could be made in this direction. This has to do with the possible increase in primary power at Muscle Shoals through the building up of the low-water flow there by water carried over from a wet period to a dry one in large storage reservoirs on tributaries. Existing information indicates that by building the two dams on the Clinch River which give the maximum storage of any possible in this basin, the primary power at Muscle Shoals might be doubled and that by building still other dams on various tributaries the primary power at Muscle Shoals might be brought up to nearly three times what seems possible under present conditions. There is already one power-navigation dam in operation on the Tennessee River and others seem to be worthy of serious consideration. It is to be remembered that these dams on tributaries permit the generation of power at their own sites, the increase of primary power at Muscle Shoals and also a similar increase at from one to all of the other power-navigation dams which may be built on the Tennessee proper. For instance, the water stored on the Clinch River would generate power there and in addition, if future investigation should remove a variety of known obstacles of unknown seriousness, the same water would participate six times in the generation of power at as many different power navigation dams before reaching the turbines in the Muscle Shoals section. Such statements are based on the known facts

that the various tributaries carry the necessary amount of water, that they have the required slopes and that a superficial examination of the topography of their drainage basins indicates that sites could be found for the necessary dams and reservoirs. They ignore the fact that no exact knowledge has ever been obtained relative to the adequacy for foundations of the various dam sites, to the impermeability of the beds of the proposed reservoirs, to the area flooded by these proposed reservoirs, to the amounts of the damages due to this overflow, to the cost of constructing the necessary dams and all their appurtenances nor the actual value of the power thereby developed as it would appear on the market. In view of all these elements of uncertainty there is little profit in discussing at this time the effect of such possibilities at Muscle Shoals or elsewhere. On the other hand, in every case these many developments on the various tributaries are warranted as far as surface indications may be accepted as guides and there should be much profit in acquiring exact knowledge on all these unknown points with a view of eliminating the impracticable sites and in the future basing the development at Muscle Shoals and elsewhere on accurate and complete data.

13. In selecting the specific section to be made the subject of a special and more detailed study it seemed clear that this should be one on the Tennessee River. At certain places on this river the undeveloped power possibilities are excellent and the interests of navigation are always present and of material importance. Such a study would then furnish a better illustration of the interdependence of power and navigation interests than would one made on a tributary where possibilities of navigation were less important. On the lower section of the Tennessee improvements for navigation are well advanced. On the middle section the Hales Bar Lock and Dam is now in operation and a good start has been made on the power navigation works at Muscle Shoals and the possibilities of these combined developments are well demonstrated in this section. In the upper section of the river, between Chattanooga and Knoxville, existing works for the improvement of navigation are only partially completed and navigation interests seem to feel that present results and future plans in this regard are inadequate. Moreover, although it is recognized that valuable power possibilities also exist in this section, attempts to develop at least one of them within the last 10 years met with failure due to adverse public opinion with respect to overflow on farm lands. If, now, instead of failure it is possible to arrive at a successful solution of this problem on the same section of river the result should be valuable not only because of the actual works of construction but also as evidence that the opportune time for a more general study of this problem has arrived.

14. Due consideration was given to the merits of different sites along this section and it was finally decided to start at the head of the Tennessee River and work downstream as far as the available funds would permit. The chief reasons for this decision are that water-power studies in the lower sections can best be made after similar studies have been completed for the upper part; there is a lively interest in Knoxville, near the head of the river, in water-power development in the Tennessee River in that neighborhood; this interest is greater than that at any other section except in the vicinity

of Muscle Shoals, where similar studies have long since taken very definite form; the section to be studied lies outside of the region where adverse public thought caused the abandonment of similar development some years ago, and yet it is close enough so that successful future developments near Knoxville should do much to favorably modify this formerly unfavorable attitude; and, finally, the chances of finding an advantageous power navigation project in this region seemed to be excellent.

15. The lock now in operation at the Hales Bar Dam provides for a minimum navigable depth over its miter sills of 6 feet. The same depth is adopted in the plans for the locks at Muscle Shoals. This is the minimum depth provided by canalization on other improved rivers elsewhere in this country and is the minimum depth considered in tentative studies of a possible system of canalization for the upper Tennessee made in previous reports from this district. It was, therefore, assumed without further study that any power navigation dam below Knoxville should give a depth of at least 6 feet over its miter sills. With this point in view the crest of the proposed dam was given the minimum elevation 799. This will give a minimum depth of 6 feet at Knoxville and up to a point just below the junction of the Holston and French Broad Rivers, where, if these rivers are ever to be canalized, it seems probable that the next dam should be built.

16. It is evident that the farther downstream a location can be found for a dam whose crest is at elevation 799 the higher this dam will be. The higher the dam the higher the head at ordinary stages and the greater the amount of power that can be generated there; also the smaller the proportional effect of flood stages on the generation of power. Generally speaking, a satisfactory power dam causes more or less overflow and consequent damage due to this cause, and in this case it is proper to choose a site which will give rise to such claims for damage provided that the amount of these claims added to other construction costs does not make the entire project uneconomical.

17. A careful study of the foregoing considerations and of all the information available which pertained to the topography of this region led to the selection of a site at Coulter Shoals, 44 miles below the head of the river and 40 miles below Knoxville, as the most promising one, and all further work on the location of the first dam below Knoxville was done with a view to developing the possibilities of this site. By following this method most of the data essential for the study of alternative positions farther upstream would be obtained, and if Coulter Shoals should prove to be unsuited, but little extra investigation would be required for the complete study of any or all of these alternative sites. To take elevation 799 as the crest of a dam at the next possible site downstream was shown by the available data to involve excessive overflow, which would bring with it damages out of proportion to the benefits to be derived.

18. At the Coulter Shoals site a dam with crest elevation 799 gives a head of about 50 feet at standard low water, taken as a discharge of 3,000 cubic feet per second, and this would not be materially reduced by a pool below having sufficient depth for navigation if a navigation or power-navigation dam is built farther down the river, as is to be expected eventually. At extreme flood stage the head is

reduced to about 27 feet. At extreme low water the natural discharge of the river falls below 3,000 cubic feet per second, but this happens, as a rule, for so small a number of successive days that with moderate flashboard storage this can be tided over and with such temporary storage the operating discharge should not fall below 3,000 cubic feet per second oftener than once in 15 years.

19. As has been mentioned above, the interconnection of existing hydroelectric installations in the Tennessee Basin has been extended to Knoxville, and as the system of central power has been recommended for this region by the War Department, it is fair to presume that future developments of this character here will follow the lines recommended. This Coulter Shoals plant should then logically become a part of this interconnected system. The relative fluctuation in head is smaller than that usually found in open river installation, and it is therefore proper to use the over-all efficiency of 80 per cent adopted in the superpower survey of the Northeastern States. Also, under this assumption the flood peak reduction of the head to 27 feet is less important as in this, the upper section of the river, these peak crests are not of long duration and there should be no difficulty during flood seasons in transferring part of the load for a short time to interconnected hydroelectric plants, particularly such of these as were operating under high heads on tributaries. Finally, it is assumed that the initial installation of machinery will be one capable of utilizing 10,000 cubic feet per second.

20. Under the foregoing assumptions the minimum 24-hour low-water capacity of this plant will be 14,000 horsepower, the 24-hour capacity for 90 per cent of the time in an average year will be 18,400 horsepower, the minimum capacity at extreme flood stage is 24,500 horsepower, and in an average year from 40,000 to 44,000 horsepower is available for 57 per cent of the time. In an average year such as 1919 the power theoretically available would have been 91,500,000 kilowatt-hours primary and 145,500,000 kilowatt-hours secondary. (See Appendix J.)

21. Studies, as yet incomplete, of the river below Coulter Shoals indicate strongly that another power navigation dam can be built with profit some 30 miles lower down. This would form a pool reaching to the Coulter Shoals Dam and having a superficial area of about 10 square miles. Such a pool would form an ideal regulating basin for the discharge from the Coulter Shoals Dam and permit the water from the turbines to be discharged at varying rates in the course of 24 hours without any interference to navigation, providing only that the contingency were foreseen and certain simple arrangements made in advance. For instance, during the 3,000 cubic feet per second discharge period the Coulter Shoals plant could pass 6,000 cubic feet per second for 12 hours and then shut down completely for 12 hours, provided that flashboards were installed on the lower dam to store the excess of the first 12-hour period so that it could be distributed over the next 12-hour period. If the lower plant were in continuous operation, utilizing 3,000 cubic feet per second for this entire 24 hours, then the maximum variation in the level of the lower pool would not exceed 6 inches. Such a variation would have no effect on navigation, provided only that the initial storage in the upper pool was sufficient so that the level there at no time fell below the established minimum. Such a combination of dams would make

the upper one much more flexible in its response to variable loads and materially increase the value of that plant.

22. Mention has already been made of the storage seemingly possible above Asheville on the French Broad River. On the Holston even greater possibilities seem to lie within reason, while there are undoubtedly possibilities of still more storage on the tributaries of both these rivers. The average discharge of the Tennessee River at Coulter Shoals for 21 years is 13,700 cubic feet per second. If, as it seems reasonable to expect, high head, large storage projects on these tributaries above the Coulter Shoals Dam come into existence in the future their effect will be to diminish the extreme flood peaks and to build up the low-water discharge. This would add materially to the value of any existing installation at Coulter Shoals. For this reason, while it seems advisable at this time to consider only the installation of enough machinery to utilize 10,000 cubic feet per second, it is proposed to design the substructure of the power house so that at least 15,000 cubic feet per second may be utilized by the installation of additional machinery at some future time. Finally, although the value of the present project for Coulter Shoals can be materially enhanced by the future construction of certain projects both above and below it, the estimates given in this report take none of these possible future improvements into consideration but deal only with existing conditions, and it is therefore felt that the figures given and the conclusions reached are amply conservative.

23. The amount of money that could properly be invested in such a development as that proposed at Coulter Shoals depends, outside of its value to navigation, on the income which would be derived from the sale of the power generated there and the amount of this income as compared with the financial outlay involved.

24. An accurate estimate of the cost of this project involves an accurate knowledge of a large number of different items for the proper investigation of which the funds available for this study were wholly inadequate. Among these may be mentioned borings to determine the character of the rock under the foundations at the proposed site, numerous important details pertaining to the construction of the locks, dam and power house, damages to farm lands, roads, bridges, houses, etc. The estimate submitted now (Appendix G) is based on a comparison with the Hales Bar Dam, that at Muscle Shoals, and others where conditions are comparable, this supplemented by as much field work as funds would permit. An examination of the Coulter Shoals site was made by the State geologist of Tennessee (Appendix H) who considered that site entirely favorable as far as he is able to judge in the absence of borings. The special maps made for this study (Plates VII, VIII, IX, X) make possible a close estimate of the number of acres overflowed or seriously damaged by increased flood heights and frequency, together with a close estimate of the value of the lands involved. It is as yet impossible to state how much land would have to be obtained through condemnation proceedings or what price would be allowed as a result of such proceedings. Roads, bridges, etc., affected are very definitely known, but the cost of relocating or rebuilding these can not yet be stated accurately.

25. This estimate covers only the cost of materials and construction, with the customary allowance for contingencies, thus showing

what would be the cost if the entire project were built by the Government, in which case there would be no charge for taxes, insurance, interest on bonds, etc., for which provision would have to be made if the work were undertaken by a municipality or by a private corporation. Under this hypothesis the initial cost is \$6,346,500, and the annual operating cost is \$257,300. If built by private interests the initial cost would probably be materially increased by expenses connected with financing, and the annual operating costs would be increased by at least \$400,000 in interest on the investment, to which would also have to be added taxes, insurance, legal and other additional overhead. No discussion of these items is attempted at this time as they would vary with the manner in which different private concerns handled these items and can best be estimated for themselves by such concerns as may be interested in this matter. The amount of the income depends upon the percentage of the power generated that can be sold and on the price at which it can be sold. With respect to the market, it seems proper to assume that this plant will be connected with the existing interconnecting net of power lines, two of these lines passing within less than 10 miles of the Coulter Shoals site. In this way this plant would be connected with Knoxville, where there is now a demand for power in excess of the supply and where is the nearest industrial center where considerable future growth is to be expected. In addition, through this net of power lines excess power could be sent throughout the eastern part of the State of Tennessee and into northern Georgia and the Carolinas. The Alabama Power Co., which is interconnected with this net, is now building the Mitchell Dam on the Coosa River to meet the expected increase in demand of the immediate future. It is believed to be certain that by the time the Coulter Shoals project could be completed and put into operation all the power which could be produced there would be absorbed by the then existing market in this region. A definite analysis demonstrating this is impossible at this time, largely because on the date on which this is being written the future status of the Muscle Shoals development is still uncertain and its potential effect on the power market throughout this section of the country completely overshadows all other factors in this problem.

26. The price at which power is sold depends upon the size of the power using installation, that is, the maximum amount which it may demand, the amount actually used, the load factor under which it operates, and whether the power used is primary or secondary. A careful analysis has been made of the rates charged by the power companies now interconnected with the southeastern power net, also of the rates quoted in the super power survey of the northeastern States and of the costs of steam-operated plants in both regions, and from this analysis it seems safe to estimate that the power could be sold at an average of 1 cent per kilowatt hour at the switchboard. Assuming that the primary power operated under a 70 per cent load factor and the secondary power under one of 50 per cent and that both were sold at an average of 1 cent per kilowatt hour the total gross annual income would be \$1,368,000 in an average year, \$1,116,000 in a year of extreme low water, and \$1,473,000 in a high-water year. In an average year the annual operating cost would be \$257,300/136,800,000, or 1.9 mills per kilowatt hour. It would appear that the difference between this cost and a selling price of an

average of 10 mills should be enough to take care of all additional costs due to corporate management and leave a satisfactory margin of profit. It is, therefore, concluded that from all information now at hand this, as a power project, will be a meritorious one and that further study of details and the preparation of detailed designs and estimates should be continued at this time.

27. In the report dated January 15, 1921, there is given a short history of the improvements in the interest of navigation made or proposed for this section of the Tennessee River. Still, more briefly stated, this section has been under improvement for nearly a century. So far all work has been done with a view to improving the open-channel conditions and providing a navigable depth of 3 feet at extreme low water. This project has not yet been fully completed and yet at certain places where all improvement that is possible has been made it is found that the channel in which this depth actually obtains is too narrow and difficult to be navigated safely in fogs or bad weather. In addition to this the current at such places is so swift at low stages that upstream navigation is impracticable except for the more powerful boats and with these the "squat" is so great that the permissible draft of these boats is actually reduced to $2\frac{1}{2}$ or 2 feet.

28. The project for a 3-foot low-water open-channel depth has been completed for a considerable distance above Chattanooga for several years and yet there has been no tangible increase in the use of this section of the river. Both with a view of saving money and also of testing out the actual demand for further improvement of this type in this section of the river, all new work for the further improvement of open-channel conditions was suspended in the summer of 1920. During the two years which have elapsed there has been no perceptible interest among pilots or boat owners in the resumption of this class of work. It is believed that the best conditions obtainable by open-channel methods do not make possible in this section of the river a type of commerce which can show profitable operation on a large scale. This opinion was foreshadowed in the report on the survey of 1909 in which a system of canalization by the construction of 11 locks and dams between Chattanooga and Knoxville was discussed, and partial canalization, to the extent of two locks and dams, was recommended. One of these, below the mouth of the Clinch River near Caney Creek, was approved by Congress and the other, about midway between Knoxville and the site now proposed at Coulter Shoals, was rejected in favor of continued open-channel work.

29. The high power-navigation dam at Coulter Shoals, as discussed in the present report, would create one pool reaching nearly to the head of the river and covering the same section which would have been covered by the one dam which was recommended and rejected in 1909 and the next two below it which were discussed but not recommended at that time. The present harbor at Knoxville includes an improved shoal three-fourths of a mile long wherein the current is swift, and navigation is difficult and where terminal facilities are practically out of the question. The river terminal possibilities are thereby reduced by 50 per cent at this city. The pool now under consideration would give a slack-water depth of 6 feet or more over this shoal and along the entire city frontage on the river. The project recommended in 1909 would have extended this pool down the

river from Knoxville for 13 miles; that herein discussed would make a continuous pool 40 miles long below that city. The three locks and dams discussed in 1909 would have required three separate operating forces; that herein discussed will require but one. The cost of constructing the three locks and dams was estimated at 1909 prices to be \$2,825,222; at present prices this cost would probably not be less than \$5,000,000. The cost of the high head improvement now suggested is \$5,265,600 for the dam, power houses, their equipment, flowage damages, etc., and \$1,080,900 for the locks and accessories. None of the three dams formerly considered would have produced enough power to be worth developing; that now proposed will produce enough to be of perceptible benefit throughout the whole neighboring region. In connection with the Muscle Shoals project consideration has been given to the proposal that the Government pay the cost of the construction of the locks and a power company or other agency pay the cost of the dam, power house, etc. If this division of costs were made at Coulter Shoals, the Government would obtain for \$1,180,900 an improvement for navigation which would be more efficient than the one considered 13 years ago and this at a cost less than one-half that proposed at that time, or less than one-fourth of the present cost of the former plan. Under this division of costs the proposition would be more attractive to power interests and easier to finance and the power from this dam would give an added impetus in this section to the industries on which navigation must depend for traffic.

30. It is to be remembered that the project for dams below Knoxville recommended or discussed in the 1909 report was rejected because existing navigation did not then warrant the expenditures involved at that time, and, furthermore, there has been no material change in the volume of business on this section of the river since that date. It will also be noted that this report does not as yet recommend the construction of a power-navigation dam in this section of the river. Available funds have not permitted this matter to be investigated as much in detail as is essential before an expression of opinion can be given. On the other hand, all the investigations which have been possible point definitely to the conclusion that a project along the lines indicated will be meritorious as providing a source of hydroelectric power sure to be needed in this region of growing industry and as furnishing at a low cost to the Government complete canalization of 20 per cent of the river between Knoxville and Chattanooga and the pool formed by the Hales Bar Dam. Below Coulter Shoals less information is at hand, but here also the indications are clear that a second high dam about 30 miles farther downstream will be justified because of the beneficial effect it will have on the manipulation of the generators at Coulter Shoals to meet hourly fluctuations of load, because it will utilize the discharge of the Little Tennessee River which would enter its pool and add $33\frac{1}{3}$ per cent to the volume of discharge and because it will add another 17 per cent to the total canalized river above Chattanooga, presumably at low cost to the Government.

31. Such a dam as this second one just mentioned would be located within the limits of the pool formed by the Caney Creek Dam recommended in 1909, which has already received congressional approval.

This third pool would receive the discharge of the Clinch River and make available for power generation at that dam a volume of water at least 58 per cent greater than that available at Coulter Shoals. Open-river improvements are practically completed from Chattanooga to the Caney Creek Dam site and this section is used by navigation as much as the sparse population of the region justifies. If connection by a series of pools were made with the upper half and Knoxville it is believed that through traffic would be revived between Chattanooga and Knoxville and be ready to take full advantage of complete canalization as soon as that could be realized. Present information does not now warrant the presentation of any project for further improvement on the upper river, but it does establish the desirability of finishing the studies now well under way in the confident belief that these studies, when completed, will point to a clear and well-defined line of procedure whereby two or three million dollars' worth of hydroelectric power now wasted annually in the upper section of the Tennessee can be conserved to the public and that a navigable depth of 6 feet on this section from Knoxville to Chattanooga can be provided by canalization at a cost to the Government well below any that has heretofore been indicated by previous projects.

SUMMARY.

32. Substantial progress has been made in bringing the essentials of stream-flow data up to date and in establishing a program of work which will keep them there. Programs for the obtaining of greater details along this line have been prepared ready to be put into operation when such details become of sufficient importance to justify the additional expenditures involved. Most of the confusion in regard to the different level systems that have been used in this region during the past half century has been cleared up, and further work of this character can proceed efficiently. The use of aerial photographs in connection with the production of new maps needed in this class of investigation has been well tested and the value of this method of mapping in work of this kind is well established. It is proposed to continue this method for such additional mapping as may be required for such additional studies as may be authorized. In further work of this kind, particularly if the amount to be done is sufficiently large, it is expected that considerable reduction may be made in unit costs and material gains made in both speed and accuracy of the results.

33. Nearly enough evidence has been obtained to establish the merit of the project for the high power navigation dam at Coulter Shoals at an approximate cost of \$6,500,000. Of that still lacking it is believed that in only two items is it possible that serious obstacles may be encountered. The first of these has to do with the character of the rock for foundations which will be developed when test borings are made. Surface conditions are favorable, as is also the geologic formation, as far as it can be determined in advance of the borings. It is believed to be all but certain that excellent foundation conditions will be shown by suitable tests. The second item is that of flowage damages. The area overflowed is moderate, approximately 3,800 acres, for the amount of power obtained, and it is believed that the amount of damages due to this overflow will not be prohibitive unless there should develop an active hostility

toward this project on the part of the property owners affected. These owners will derive a real benefit from the excellent facilities for navigation afforded by this long and deep pool extending from their properties to Knoxville by the increased deposit of rich alluvial soil on their cultivated land, and also from the additional power produced in their near vicinity, and it is believed that when all the details of the project have been perfected these advantages can be presented to these owners with sufficient clearness so that no unreasonable opposition will be encountered. Numerous details pertaining to the design of the locks, dam, power house, etc., have yet to be worked out, but no difficulty is anticipated with any of these.

34. The importance of a second dam about 30 miles below Coulter Shoals is clearly indicated, this as an additional element of the superpower system now taking form in this region, as permitting more efficient methods of operation at Coulter Shoals, as making use of the considerable flow from the Little Tennessee River which enters its pool, and above all as an essential element in the complete canalization of the Tennessee River which must be provided eventually. The next or third power navigation dam in this series is one which has already received congressional approval but whose construction has so far been postponed through causes arising out of misunderstandings on the part of the local public. This project should in its turn be revised in order that it may be in full harmony with those for the two dams which should be built above it. To complete the canalization of this river from Knoxville to Chattanooga and the Hales Bar pool other dams must be built between this third dam and Chattanooga. Present indications are that this can be done by two more power navigation dams, though this opinion is subject to revision when more complete data are at hand from topographic maps of this section which have yet to be made.

35. On the Holston and French Broad Rivers, above Coulter Shoals, as well as on some of their tributaries, there are ample surface indications that high-power dams with large storage can be built. These should be of value at the proper time as part of the future superpower system of this region. In addition, such dams would have a markedly beneficial effect on the low and high water flow not only at Coulter Shoals but at all other dams that either now exist at Hales Bar or that may be built in the future in the Tennessee River, including dams at Muscle Shoals. The power possibilities of the Little Tennessee, which enters the second pool, have been well determined by the Aluminum Co. of America; projects for their full development by this company exist and the first of a series of nine power dams with large storage has been completed and the plant is now in operation. All such development on the Little Tennessee is of direct and material advantage to the second dam indicated on the Tennessee proper and to all other dams below it. The Clinch River enters the third of the proposed pools. Here the power and storage possibilities appear to rank below those on the Little Tennessee and above those on the Holston and French Broad. Storage on this tributary will improve all developments at the third dam of the series below Knoxville and all others below that. Present indications are that full use of the storage presumably available in the basin of the Clinch would double the amount of primary power

available at Muscle Shoals. No large tributary would enter the fourth pool, but the fifth (if five power-navigation dams on the Tennessee can be made sufficient for complete canalization of this upper section) would receive the discharge of the Hiwassee River. In this basin there already exist two storage developments, and still others are known to be possible from valuable investigations already made by private interests. Regulated flow from this tributary would benefit the fifth project on the main river and all below it.

36. The foregoing paragraphs sketch with extreme brevity the main outlines of the power possibilities of the Tennessee Basin above Chattanooga. In this region it has been possible to acquire in the course of this survey definite ideas on the value of the Coulter Shoals project only. For the rest, all these other possibilities have either been studied in considerable detail by private corporations or prospected by agents in their employ. There is much to indicate that eastern Tennessee and the neighboring States are on the verge of an active development depending on these large hydroelectric projects. If the Government, by proper investigation, can establish features of essential importance which should govern in each of these projects not only as isolated developments but also in their relation to each other and to actual and potential navigation, then it will be in a position fully to safeguard the interests of navigation and the proper development of the superpower system which has already received the favorable notice of the War Department. Furthermore, if the Government has a well-considered plan of development prepared in advance, it might be possible to facilitate the action of private interests and to keep them from delays due to friction among themselves such as are now holding up desirable improvements in the Hiwassee Basin. Finally, power development, to have a market, must be accompanied by industrial development and it is from these future industries that the most is to be expected in the way of traffic on the Tennessee River and its navigable tributaries.

37. The recommendations which follow provide for a continuation of the line of investigation which should be carried forward during the coming fiscal year and one on which a good beginning has already been made. The results of this work will appear in the form of projects in which the Government will be interested because of their influence on navigation and also where it is expected that private interests will have a large proportional interest because of their bearing on the hydroelectric power situation or other industrial advantages in eastern Tennessee and the adjacent Southeastern States. The report on the preliminary survey submitted a year ago gives in some detail the reasons why thorough investigation and study of conditions of mutual importance to navigation and power in this region should be undertaken at the earliest practicable date, and the following recommendations are submitted in the belief that their adoption will be of special value in the immediate future.

RECOMMENDATIONS.

Following the estimates of cost given with the report on the preliminary survey submitted in January, 1921, it is recommended that the present work on the survey of the Tennessee River and its tributaries be continued during the next fiscal year, as follows, and

that the funds necessary for this purpose be provided to the amount of \$250,000. Cost of continuing stream-flow records is included in this amount.

A. Complete the studies for the Coulter Shoals project to include a thorough test of foundation conditions by ample borings, compile a close estimate of flowage damages, and prepare designs of locks, dam, and power-house substructure complete in all essential details. Estimated cost, \$40,000.

B. Continue field and office investigations with a view to developing the full power-navigation possibilities of the upper river from Coulter Shoals to the head of the Hales Bar pool at Chattanooga. Estimated cost, \$100,000.

C. Make preliminary field and office investigations with a view to developing the full power-navigation possibilities of the middle section of the Tennessee River between the Hales Bar Dam and Riverton, exclusive of the Muscle Shoals section. Estimated cost, \$30,000.

D. Make preliminary field and office investigations of the power and storage possibilities on the Holston and French Broad Rivers and their tributaries and of the relation which these possibilities bear to the actual or potential navigation on these rivers and on the Tennessee River, and to future power possibilities on that river. Estimated cost, \$40,000.

E. Make preliminary field and office investigations of the power and storage possibilities on the Clinch and Powell Rivers and their tributaries and of the relation which these possibilities bear to the actual or potential navigation there and on the Tennessee, and to future power possibilities on that river. Estimated cost, \$40,000.

Total estimated cost, \$250,000.

HAROLD C. FISKE,
Major, Corps of Engineers.

[First indorsement.]

OFFICE OF THE DIVISION ENGINEER,
CENTRAL DIVISION,
March 21, 1922.

To the CHIEF OF ENGINEERS, UNITED STATES ARMY:

1. The report on preliminary examination of the Tennessee River and tributaries in North Carolina, Tennessee, Alabama, and Kentucky, dated January 15, 1921, concludes with a recommendation that a broad and comprehensive survey be made "as thorough as the law or the desires of Congress and available funds will permit." In a subsequent communication dated January 27, 1921,¹ the district engineer presented an estimate of cost of the proposed survey amounting to \$515,800. Neither the views of the Board of Engineers for Rivers and Harbors on this report on preliminary examination nor the action of the department have been communicated to this office.

2. In letter¹ from the Chief of Engineers to the district engineer, dated April 31, 1921, an allotment of \$20,000 was made for the purpose of carrying on the survey work in accordance with instructions given orally to the district engineer by the Chief of Engineers. This

¹ Not printed.

allotment was coupled with the injunction to so conduct the work as to obtain, if possible, the desired results with the amount of money then allotted.

3. As the oral instructions referred to in the preceding paragraph are not of record in this office, the division engineer finds it difficult to submit either a definite statement of his views, or definite recommendations, as required by paragraph 1034, Orders and Regulations.

4. The work heretofore accomplished and that proposed by the district engineer for the next fiscal year indicate, contrary to usual practice, that the primary purpose of the survey is a detailed investigation of the power possibilities of the Tennessee River and its tributaries, with merely incidental reference to the requirements of navigation.

5. A survey of this river in the interest of navigation should include an analysis of the benefits to navigation derived from the expenditures made under existing projects and an estimate of the increased benefits that would follow a modification or enlargement of these projects. From such a study it should be possible to determine approximately the maximum amount which the United States would be justified in expending to secure the increased navigation facilities.

6. The district engineer assumes that the development of power will develop industry in the valley, and that this industrial growth will require increased transportation facilities, yet such a result did not follow the construction of the power-navigation dam at Hales Bar. He also assumes in the proposed Coulter Shoals combination dam that the United States would be justified in paying for the cost of the lock and its accessories as it did at Hales Bar, but no evidence is presented as to whether such an investment would yield a reasonable return.

7. The survey as it now stands is incomplete and further work is necessary to determine the advisability of providing increased navigation facilities through combination power-navigation dams, but in the opinion of the division engineer a conclusion can be reached without the aid of a detailed plan for the development of the water power of the valley.

8. A continuation of the stream flow investigation is believed to be desirable, but the cost of continuing this for one year should not exceed \$5,000 if done in cooperation with local, State, or other national interests. Borings are essential at all selected dam sites, whether for navigation alone or for combined power and navigation dams.

9. The cost of additional work necessary for an intelligent consideration of the proposed dam at Coulter Shoals should be much less than the \$40,000, as estimated. For the reach between Coulter Shoals and Chattanooga the estimate calls for \$100,000. It is understood that all needed aerial photographic work has been completed for this part of the river, so that the cost of contouring the areas that would be overflowed by a given system of dams should not be large.

10. Studies heretofore made indicate that prospects for power are not good between Hales Bar and Riverton, except at Muscle Shoals. The banks are relatively low, and it does not seem possible to build dams of sufficiently high lifts for successful commercial development of power. Flowage damages for even moderate lifts appear to be

excessive. If the information available from previous surveys is not adequate, it can be sufficiently augmented at moderate cost.

11. The estimate includes an item of \$40,000 for investigations on the Holston and French Broad Rivers. Neither the preliminary examination in this case nor any one of the series of examinations made in the past indicate the advisability of any large expenditure at this time in the interest of navigation. The same thing seems to apply with equal or greater force to the suggested expenditure of \$40,000 for the investigation on the Clinch and Powell Rivers.

12. It is recommended that the scope of the investigation be defined by the Chief of Engineers, that the district engineer be then called upon to submit a revised estimate covering the entire cost (not merely the amount needed for next season), and that the estimate be prepared in greater detail than that herewith.

13. Attention is invited to the following apparent errors:

On page 195 the last line of table should read "1.75 mills" instead of "0.75 mills."

On Plate V the elevation on profile sketch for the crest of Hales Bar Dam, United States Engineer datum, does not agree with the elevation given in the table on the same sheet.

C. W. KUTZ,
Colonel, Corps of Engineers, Division Engineer.

APPENDIX A.

STREAM-FLOW MEASUREMENTS.

Work was started under the cooperative agreement between the United States Engineer Department and the United States Geological Survey on October 1, 1920, and the district office of the Survey was moved from Nashville to Chattanooga, where space was provided in the offices of the Engineer Department. This arrangement has resulted in close cooperation between the two departments and a direct saving of time and money in the collection of stream-flow data.

Prior to October 1, 1920, the United States Geological Survey, in cooperation with the Tennessee Geological Survey, was operating 28 gauging stations on the Tennessee River and several of its important tributaries. The length of time that these had been maintained varied from only a few months in some instances to 20 years or thereabouts in certain other instances, the records having been published in the annual Water Supply Papers of the Geological Survey.

While the gauging stations in operation at that time serve very well as base stations, the number was entirely inadequate for a comprehensive study of the entire river system, such as was proposed by the Tennessee River survey. It was therefore decided to increase that number by reestablishing 16 stations which had been discontinued in past years for financial reasons, and at which short records had been obtained; and to establish 15 entirely new stations at other critical points throughout the basin. It was found that nearly all of the abandoned stations required new equipment, and in some cases the location of the gauges was changed slightly to obtain better and more permanent channel conditions.

Immediately after the transfer of this office to Chattanooga we set about making examinations for the proposed gauging stations, and by December 31, 1920, 19 of these had been placed in operation; the remainder were completed by February 15, 1921. Hence, at the present time we are maintaining 59 gauging stations at which more than one year of continuous record has been obtained. All but two of the new stations are equipped with standard chain and weight type or vertical staff gauges, the two exceptions being recording instruments which were supplied by private parties. The United States Weather Bureau furnished the gauge record at 11 stations free of charge, and private parties are paying for observers at 11 additional stations, leaving 37 stations at which observers are paid from Federal account, the average monthly pay being \$5. The Weather Bureau observers make only one observation daily, but in nearly all other cases readings are taken both morning and evening.

The accompanying map shows the distribution of gauging stations throughout the basin to be as follows:

Name of stream.	Number of gauging stations.	Name of stream.	Number of gauging stations.
Tennessee River.....	3	Tuckasee River.....	2
Holston River.....	1	Scotts Creek.....	1
North Fork, Holston River.....	2	Oconalufy River.....	1
Middle Fork, Holston River.....	1	Cheoah River.....	1
South Fork, Holston River.....	2	Clinch River.....	4
Watauga River.....	1	Powell River.....	2
Doe River.....	1	Emory River.....	1
French Broad River.....	4	Hiwassee River.....	3
Davidsons River.....	1	Valley River.....	1
Swannanoa River.....	1	Nottely River.....	1
Nolichucky River.....	4	Ocoee River.....	5
Big Pigeon River.....	2	Sequatchie River.....	2
Little Pigeon River.....	1	Elk River.....	1
Little Tennessee River.....	4	Duck River.....	3
Cullasegee River.....	1	Buffalo River.....	1
Nantahala River.....	1		

The five stations on the Ocoee River are maintained through special cooperation with the Tennessee Power Co., which company has borne a large part of the expense of maintenance in the past and will in the future bear the entire expense.

The red circles on the map indicate stations which were in operation prior to October 1, 1920; the solid red dots indicate those established since that date.

As was the case with most Government offices, the amount of money available to this office for stream-gauging work was considerably reduced after July 1, 1921, necessitating a reduction in personnel from six to three. A new cooperative agreement was entered into at that time to cover the cost of carrying the work on during the fiscal year 1922. Under this agreement the Engineer Department agrees to pay \$4,000 and the United States Geological Survey and the Tennessee Geological Survey each contribute \$3,000, making a total of \$10,000 to be expended in the Tennessee River Basin. None of the gaging stations were discontinued, however, and every effort is being put forth to obtain satisfactory discharge ratings at all points at the earliest possible time. Four hundred and forty-three discharge measurements have been made since October, 1920, being an average of a little over seven for each station in the basin. In general, the rating curves for most of the stations are well developed through low and medium stages and a few are completed through high stages.

We had not expected to obtain complete ratings at all stations within a single year for the reason that the periods of high water are so infrequent and of such short duration that not more than 4 or 5 stations can be visited with the present force before the water has again receded to somewhere near normal. At this rate, if the allotment is not increased, it may require several years before we can obtain complete ratings at all of our river stations. The ratings thus far obtained, however, are in most cases sufficient to allow reliable estimates of discharge to be made for 90 to 95 per cent of the time.

Work in the North Carolina section of the Tennessee River Basin has been performed by engineers of the Asheville office of the United States Geological Survey; Mr. Warren E. Hall, district engineer. Special acknowledgment is due Mr. Hall for his activity in this connection. The field work on those stations is in excellent shape. A comparatively large number of discharge measurements have been made at each station, and the ratings for all ordinary stages are well developed.

The following table shows the amount of money expended to date and unit costs based upon the number of stations maintained and the number of discharge measurements made.

TABLE 1.—*Expenditures for stream gauging in Tennessee Basin.*

Month.	Expenditures United States Engineer Department.	Expenditures United States Geological Survey.	Expenditures Tennessee Geological Survey.	Total expenditures on stream gauging work.	Number of regular employees.	Number of stations maintained.	Number of discharge measurements.	Cost per gauging station.	Cost per discharge measurement.
1920.									
October.....	\$544.61	\$178.00	\$41.00	\$763.61	2	22	17	\$34.69	\$44.88
November.....	829.99	276.08	4.80	1,110.87	4	37	32	28.48	34.72
December.....	1,346.57	439.76	37.12	1,823.45	6	53	30	34.40	60.78
1921.									
January.....	1,283.52	232.00	4.80	1,520.32	6	56	41	27.16	37.10
February.....	990.34	237.60	4.80	1,332.74	6	60	34	20.55	36.27
March.....	999.49	242.20	10.98	1,252.67	6	60	41	20.89	30.57
April.....	992.29	210.64	89.88	1,292.81	6	60	40	21.54	32.32
May.....	458.14	332.36	72.00	862.50	5	60	9	14.37	95.83
June.....	290.15	327.08	103.84	1,221.07	4	59	7	20.70	174.45
July.....	505.81	500.00	46.14	1,051.95	5	59	50	17.83	21.04
August.....	237.50	434.04	63.40	734.94	3	59	20	12.45	36.74
September.....	286.00	624.80	103.18	1,013.98	4	59	20	17.17	50.70
October.....	367.50	499.84	47.78	915.12	4	59	21	15.51	43.60
November.....	336.00	494.68	22.94	853.62	4	59	22	14.46	38.78
December.....	356.00	673.36	79.34	1,108.70	4	59	22	18.79	50.39
1922.									
January.....	296.00	611.48	196.00	1,103.48	4	59	37	18.70	29.82
Total.....	10,119.91	6,813.92	928.00	17,861.83	.....	55.4	443	322.50	40.33

Previous to July 1, 1921, the Engineer Department bore nearly 70 per cent of the cost, this being largely due to the cost of installation of new stations; since that date the proportion borne by that department is about 35 per cent. The Tennessee Geological Survey money has been held in reserve and will be spent at a much faster rate during the remainder of the fiscal year.

The manuscript for the 1919-20 progress report giving the results of all data collected for those years has been completed and transmitted to Washington. This will be published by the Geological Survey as one of the regular Water Supply Papers. Due recognition of the cooperation with the Engineer Department and the Tennessee Geological Survey will be given, the statement in regard to this having been approved by the Chief of Engineers. Copies of all data contained in this manuscript have been filed with the Engineer Department office in Chattanooga. Special studies have been made at several important stations and estimates of discharge worked out for back years when no record was published.

Having completed the field work for 1921, we are now engaged in preparing estimates of the discharge up to September 30, 1921, the end of the water year. These have already been completed for 17 regular stations and good progress is being made along that line. It is expected that all estimates will be completed by May 1 of this year and the data assembled in manuscript form for printing.

A table is presented herewith to show the status of the stream gauging work at the present time.

TABLE 2.—*Status of stream gauging work in Tennessee Basin.*

River.	Location.	Type of gauge.	Number of months' record since Oct. 1, 1920.	Number of discharge measurements.	Condition of rating curve.	Discharge estimates completed to—	Remarks.
Buffalo.....	Flatwoods, Tenn.....	Staff.....	16	5	Fair below 1,200 second-feet.	Oct. 1, 1921	High-water measurements needed.
Cheach.....	Johnson, N. C.....	do.....	13	5	Good for low water.....	.....	Do.
Clinch.....	Cleveland, Va.....	Chain.....	15	7	Good for ordinary stages.....	Oct. 1, 1921	Do.
Do.....	Clinton, Tenn.....	do.....	16	6	Excellent below 30,000 second-feet.	do.....	.....
Do.....	Lone Mountain, Tenn.....	do.....	16	5	Good below 25,000 second-feet.	Mar. 31, 1921	Control slightly shifting.
Do.....	Speers Ferry, Va.....	Staff.....	15	7	Poor at all stages.....	.....	Additional measurements needed.
Cullasegee.....	Franklin, N. C.....	do.....	12½	5	Good at low and medium stages.	.....	High-water measurements needed.
Davidsons.....	Brevard, N. C.....	Chain.....	13½	8	Good for medium stages.....	.....	High-water rating incomplete.
Doe.....	Valley Forge, Tenn.....	do.....	15	8	Good at low stages.....	.....	High-water measurements needed.
Duck.....	Centerville, Tenn.....	do.....	16	5	Good from 400 to 8,000 second-feet.	Oct. 1, 1921	.....
Elk.....	Elkmont, Ala.....	do.....	16	3	Good below 8,000 second-feet.	Oct. 1, 1920	Extreme high-water measurements needed.
Do.....	Estill Springs, Tenn.....	Staff.....	13½	7	Good below 1,000 second-feet.	.....	High-water measurements needed.
Duck.....	Columbia, Tenn.....	Tape.....	16	6	Fair throughout.....	Oct. 1, 1921	Control slightly shifting.
Do.....	Normandy, Tenn.....	Staff.....	13½	7	Fair below 1,500 second-feet.	.....	Measurements plot irregularly.
Emory.....	Deermont, Tenn.....	Chain.....	16	6	Fair below 2,500 second-feet.	Oct. 1, 1920	Additional measurements needed at high water.
French Broad.....	Asheville, N. C.....	Staff.....	16	11	Good throughout.....	.....	Additional high-water measurements needed.
Do.....	Blantyre, N. C.....	Chain.....	13½	12	Good for low and medium stages.	.....	Shifting channel and control.
Do.....	Dandridge, Tenn.....	Staff.....	16	5	Fair from 2,000-30,000 second-feet.	Oct. 1, 1920	High-water measurements needed.
Do.....	Oldtown, Tenn.....	Chain.....	14½	6	Good below 4,000 second-feet.	.....	.....
Hwassee.....	Charleston, Tenn.....	Staff.....	13	7	Good below 10,000 second-feet.	.....	Backwater from Tennessee River affects high stages.
Do.....	Reliance, Tenn.....	Chain.....	16	18	Fair throughout.....	Oct. 1, 1920	Control slightly shifting.
Do.....	Murphy, N. C.....	do.....	16	5	do.....	.....	Do.
Holston.....	Rogersville, Tenn.....	Staff.....	16	5	do.....	Oct. 1, 1921	Do.
Little Pigeon.....	Sevierville, Tenn.....	do.....	14	5	Rating incomplete.....	.....	Additional measurements needed.

Little Tennessee.	Calderwood, Tenn.	Recording.	13	6	Good from 2,000 to 10,000 second-feet.	Jan. 1, 1922	High water measurements needed.
Do.	Franklin, N. C.	Chain.	12	15	Good throughout.	Jan. 1, 1922	Control slightly shifting.
Do.	Judson, N. C.	Staff.	12	5	Fair throughout.	Jan. 1, 1922	Additional measurements needed.
Do.	McGhee, Tenn.	Chain.	16	5	Excellent below 28,000 second-feet.	do.	Rating incomplete. Additional measurements needed.
Nolichucky.	Embreeville, Tenn.	do.	16	5	Fair from 500 to 2,000 second-feet.	do.	High water measurements needed.
Do.	Greeneville, Tenn.	do.	16	6	Good below 10,000 second-feet.	do.	Do.
Do.	Morristown, Tenn.	do.	144	6	Fair from 400 to 2,000 second-feet.	do.	Very shifting channel.
North Fork Holston.	Mendota, Va.	do.	15	7	Good below 2,500 second-feet.	do.	Additional high water measurements needed.
Do.	Saltville, Va.	do.	15	7	Good below 1,000 second-feet.	do.	Additional measurements needed.
Nantahala.	Wesser, N. C.	do.	7	1	Abandoned; discontinued May 1, 1921.	do.	Control very shifting.
Do.	Almond, N. C.	Staff.	12	11	Good at low and medium stages.	do.	Control shifts slightly.
North Toe.	Spruce Pine, N. C.	Chain.	16	5	Fair for low stages.	do.	High-water rating incomplete.
Norfeley.	Ranger, N. C.	Staff.	16	13	Good throughout.	do.	Control slightly shifting.
Middle Fork Holston.	Chilhowie, Va.	Chain.	15	7	Poor at all stages.	do.	High water measurements needed.
Ocoee.	Emf, Tenn.	Recording.	16	8	Good below 3,000 second-feet.	Jan. 1, 1922	Additional high water measurements needed.
Do.	Parksville, Tenn.	do.	10	6	Good below 8,000 second-feet.	do.	High water measurements needed.
Do.	McHarge, Tenn.	Staff.	16	3	Good from 400 to 2,000 second-feet.	do.	Additional high water measurements needed.
Oconalufy.	Cherokee, N. C.	Chain.	12	9	Good at low and medium stages.	do.	Additional high water measurements needed.
Pigeon.	Newport, Tenn.	do.	16	5	Good below 8,000 second-feet.	July 31, 1921	High water measurements needed.
Do.	Crabtree, N. C.	do.	134	7	Good at low water.	do.	Additional high water measurements needed.
Powell.	Arthur, Tenn.	do.	16	5	Good below 5,000 second-feet.	do.	High water measurements needed.
Do.	Pennington, Va.	do.	15	7	Good below 500 second-feet.	do.	Additional high water measurements needed.
Swannanoa.	Biltmore, N. C.	Staff.	14	21	Excellent throughout.	do.	Insufficient measurements. Shifting control.
Scotts Creek.	Sylvia, N. C.	Chain.	12	8	Good at low and medium stages.	do.	Backwater from Hales Bar Dam affects accuracy of rating.
Sequatchie.	Whitwell, Tenn.	Staff.	14	7	Good below 1,000 second-feet.	do.	Control slightly shifting at low water.
South Fork, Holston.	Bluff City, Tenn.	Chain.	16	5	Good below 5,000 second-feet.	do.	
Do.	Chilhowie, Va.	do.	15	7	Poor at all stages.	do.	
Tennessee.	Chatanooga, Tenn.	Chain and staff.	13	8	Fair throughout.	Jan. 1, 1922	
Do.	Knoxville, Tenn.	Staff.	16	11	Good throughout.	do.	

TABLE 2.—*Status of stream gauging work in Tennessee Basin—Continued.*

River.	Location.	Type of gauge.	Number of months' record since Oct. 1, 1920.	Number of discharge measurements.	Condition of rating curve.	Discharge estimates completed to—	Remarks.
Tennessee	Florence, Ala.	Staff	16	0	Excellent throughout	Jan. 1, 1922	Measurements by Hugh L. Cooper Co. and United States Army Engineers during 1920, 1921 check old curve.
Toccoa	Dial, Ga.	Recording	16	5	Good throughout	do.	Curve needs checking.
Do.	Morganon, Ga.	do.	16	6	do.	do.	Do.
Tuckasegee	Bryson, N. C.	Staff	13½	11	Good at low and medium stages.	do.	New curve developed.
Do.	East Laport, N. C.	do.	13½	7	do.	do.	
Valley	Tomolofa, N. C.	Staff	16	10	Good throughout	do.	
Watauga	Butler, Tenn.	Chain	15	7	Good below 1,000 second feet.	do.	High water measurements needed.

The number of discharge measurements shown on this table does not check with the preceding table, for the reason that quite a number of miscellaneous measurements were made at points other than at regular gauging stations.

WARREN R. KING,
District Engineer, United States Geological Survey.

APPENDIX B.

FLOOD PROFILES.

From the start, in this investigation, the necessity for obtaining full information concerning flood heights made itself felt. Such information was needed in order to plan intelligently the height of power navigation dams; for determining what lands in the past had been subject to overflow from natural causes, and the frequency of such overflow; and, finally, for gaining a correct conception of the nature of the flood problems that are confronting certain municipalities situated along the Tennessee River.

To this end, all data pertaining to flood heights which had been obtained in the course of previous surveys was collected, converted into elevations, referred to a common datum plane, and platted on profiles for proper coordination. This data was supplemented by high water elevations obtained by field parties sent out from this office during the past year and from early gauge records. The resulting profiles, which cover stretches of the Tennessee River from its head to Chattanooga, and from Chattanooga to Hales Bar Dam, respectively, are shown in Plates II and III.

The great flood of 1867, the highest on record on the upper Tennessee, has been platted with considerable accuracy, thanks to the many high-water marks that were established at the time by residents along the river. Many of these marks have remained well preserved to this date. Information relating to other floods was found to be less plentiful. Thus, the next highest flood, that of 1875, yielded scant data, but its profile was readily established because it paralleled closely that of 1867. Plate II shows that the height of the flood crest in 1867 on the upper river was remarkably uniform. Actual heights above extreme low water were: 46.6 feet at Knoxville; 44.2 feet at Loudon; 43.3 feet at Kingston; and 45.3 feet at Rockwood. At Chattanooga, however, the rise amounted to 58.6 feet, and below this point the rise was even greater.

Particular interest attaches to the 33-mile stretch of river between Chattanooga and Hales Bar, known as the mountain section of the Tennessee. (See Pl. III.) The river, for a distance of over 20 miles, winds through a deep gorge which has many constrictions. Before the construction of the Hales Bar Dam this section was particularly dangerous to shipping on account of the many shoals, whirlpools, and narrow defiles. The constricted portion, about 10 miles in length, extends from Tumbling Shoals, at mile 198.4, to just about Savannah Towhead (now submerged), at mile 208.5. At certain points near the "Suck," the "Pot," and the "Pan" the channel measured less than 300 feet across at extreme low water before the dam was built, and at the present time the width at the Suck and the Pot is under 500 feet. For about one-quarter of the 10-mile stretch the original width was not much over 400 feet and to-day is about 600 feet. When it is taken into account that the normal width of the river is in excess of 1,000 feet, the seriousness of these constrictions becomes apparent.

During high-water stages gorging takes place, attended by a marked rise in the water surface. At the Suck the flood of 1867 rose to nearly 70 feet above extreme low water. So far as is known, this is the greatest difference between high and low water stages recorded on any portion of the Tennessee River. It is this piling up of the water that is largely responsible for the high flood stage at Chattanooga previously mentioned. This is obvious by reference to Plate III. The profiles of the floods of 1867 and 1875 show very pronounced gorging, and since the dam was built (October, 1913), this action, though less pronounced, is still reflected in the profiles of the floods which have since occurred. That of 1917 is strong evidence that the flood stages experienced at Chattanooga since the construction of the dam are no more abnormal than they were previous to its construction. There is, nevertheless, a persistent belief among the citizens of that city that the high flood stages there are attributable mainly to the presence of the dam.

In February, 1921, the district engineer caused a permanent record to be made of the flood heights of that date throughout the entire length of the mountain section. The U. S. S. *Ocoee*, in charge of the writer, was detailed for this purpose, and starting from Hales Bar Dam when the flood was about to crest, proceeded upstream, stopping

at intervals of about a mile or less for the placing of high-water marks. These consisted of broad bands of white paint accompanied by date, placed on conspicuous ledges and rocks, and of galvanized iron strips bearing the date by means of punch marks nailed to trees. A complete record was kept of the location and description of all marks for future reference and recovery. In all, 50 paint marks were made, usually in pairs on opposite shores, and 44 galvanized strips were fastened to trees, requiring in all two days' work. The following May a survey party determined the elevations of all paint marks by running accurate levels. Proper correction was applied to the elevations of any marks placed after the flood had begun to recede, and the resulting data plotted in the form of the profile shown in Plate III. This flood attained a stage of only 34.5 feet at Chattanooga and passed over the Hales Bar Dam 12.4 feet deep. Its discharge at crest was 210,000 cubic feet per second, representing a flood stage which is reached nearly every year. Though only a moderate flood, its profile shows the same characteristic piling up in the mountain section as in the case of the larger floods, but in a less degree, proving that even at this comparatively low flood stage the gauge reading at Chattanooga is affected by gorging in the constricted mountain section. It would appear from the preceding that it is this gorging that determines mainly the stage at Chattanooga, and that the net effect of backwater from the dam, whatever it may amount to, is of minor significance, and this the less so the higher the flood stage.

GERARD H. MATTHES,
Assistant Engineer.

APPENDIX C.

REPORT OF THE LEVEL DATUMS OF THE CHATTANOOGA DISTRICT.

During May and June, 1921, Mr. H. B. Hooper, junior engineer, was detailed by this office to run a double-rodged line of check levels from Chattanooga to Widows Bar Dam, for the threefold purpose of obtaining a high-water profile; of checking the bench-mark elevations being used in the construction of the Widows Bar Dam with those used at the Hales Bar Dam; and of clearing up doubtful matters pertaining to the various level datums that have been in use along this part of the river.

The starting point of Mr. Hooper's survey was B. M. No. 82 at the southwest corner of Market and Sixth Streets, in Chattanooga, this being the initial point of all previous leveling operations of any importance in this section. Its elevation above mean sea level, as determined by the Coast and Geodetic Survey, is 674.162, and as referred to the old Engineer Department datum in use in this district 684.017, a difference of 9.855 feet. Mr. Hooper's levels referred throughout to Coast Survey datum, and brought out the fact that within narrow limits the equation -9.855 feet applies to all Engineer Department bench marks from Chattanooga to Bridgeport, Ala., including those set during the surveys made in 1891, 1899, and 1909.

At Widows Bar Dam Mr. Hooper's elevations were 2.98 feet higher than those in use there, showing that the latter differ by 12.83 feet from Engineer Department datum in use between Chattanooga and Bridgeport. The elevations used in the construction of the dam, however, proved to be correct with respect to those used in the building of the Hales Bar Dam, although referring to a different datum.

During the latter half of 1921 Mr. Hooper, while making topographic surveys in the valley of the Tennessee between Knoxville and Chattanooga, was directed to run check levels connecting Engineer Department with Coast Survey bench marks wherever opportunity for so doing presented itself without requiring much time or expense. This he did at several localities with the results listed below, the differences in each instance being the amounts by which Engineer Department elevations are higher than Coast and Geodetic Survey elevations.

Locality.	Difference in feet.		Locality.	Difference in feet.	
	1909 survey.	1891 survey.		1909 survey.	1891 survey.
Knoxville, Tenn.....	9.81	9.81	Loudon, Tenn.....	9.20	9.79
Concord, Tenn.....	9.79	9.79	Chattanooga, Tenn.....	9.86	9.86
Lenoir City, Tenn.....	9.47	9.76			

It will be noted that the 1891 survey levels show more nearly constant differences than do those of the 1909 survey, and would therefore appear to be the more reliable of the two. Since the later levels have commonly been regarded as an improvement over the earlier, the value of running check levels as described is apparent. It is much to be desired to continue the practice of making such check connections at other points along the upper Tennessee River, to the end that all bench mark elevations along this part of the river may eventually be corrected by reference to the checks so obtained. This will obviate the necessity of rerunning the level lines along 188 miles of river.

Much confusion has been caused in this district by the existence of more than one plane of reference for levels. In previous surveys three distinct datum planes have been recognized, all purporting to refer to sea level. In addition, a separate assumed datum has been in use on each of the larger tributaries. In several instances no connection was ever made between the latter and the datums used along the main river, and the true elevation above mean sea level of these assumed planes remains to this day unknown.

The three reference planes used on the main river are:

1. The datum used in the surveys of the Tennessee River made above and below Chattanooga in 1891, 1899, and 1909; this is herein referred to as the Engineer Department datum.

2. The datum used in the precise level lines run in 1895 under the direction of Capt. Theodore A. Bingham, along the Tennessee River from Decatur, Ala., to Pittsburg Landing, Tenn. This has usually been referred to as the preliminary mean gulf level datum of the Mississippi River Commission, but it actually differs from the latter by several feet. It is here referred to as the Bingham datum.

3. The datum used in the precise level lines of the United States Coast and Geodetic Survey and United States Geological Survey, and which is here referred to as the mean sea-level datum.

A fourth datum plane was adopted in surveys made during the period 1913-1917. This is not, however, here classed as a separate datum, because it was clearly intended to have been identical with that described under (2) above. It differs from it by about 1 foot.

Plate IV shows the relative positions of these datum planes, and indicates that bench-mark elevations based on Engineer Department datum should be reduced by 9.855 feet in order to refer to mean sea level; also, that elevations established by Captain Bingham's survey should be increased by 4.056 feet in order to agree with mean sea-level elevations.

In order to clarify the situation as regards the use of these various datum planes and to bring out their interrelation, there is presented herewith a brief description of each datum together with a statement of the surveys and engineering works in which it has been used.

ENGINEER DEPARTMENT DATUM.

The early surveys made by the Engineer Department on the Tennessee River antedated by many years the precise level lines of the Coast and Geodetic Survey. On this account an initial reference point for levels was established in 1871 at Chattanooga, which is well preserved at the present day. It is a small level cut 1½ inches wide by one-half inch deep in the water table of what formerly was the First National Bank Building, on the southwest corner of Market and Sixth Streets. The mark is on the north side of the building near a down spout, and is just wide enough to admit the bottom of a leveling rod. The building is at present occupied by a grocery store owned by Saffer & Krug. The bench mark was established by Assistant Engineer F. T. Hampton acting under instructions from Maj. W. McFarland. The elevation was at first assumed to be 100, but in 1876 the height above sea level was determined by barometrical observations and comparisons with railroad elevations. At a later date the elevation was again referenced to railroad levels and fixed at 684.017 feet, and has been so used up to the present time.

In 1875 the river gauge established at the Walnut Street Bridge was referred to it, and since that time it has been known as the gauge bench mark. It has also been referred to in the reports of the Chief of Engineers as "U. S. B. M. No. 82."

Its elevation above mean sea level as determined by the Coast and Geodetic Survey proved to be 674.162 feet or 9.855 feet lower than by Engineer Department datum.

The following surveys of the Tennessee River are referred to Engineer Department datum:

1. The 1891 survey above Chattanooga.
2. The 1891 survey between Chattanooga and Shellmound.

3. The 1899 survey between Shellmound and Browns Ferry, Ala.
4. The 1899 special topographic surveys in the mountain section below Chattanooga.
5. The portion of the 1909 survey extending from the head of the river to Browns Ferry, Ala.

This datum was used in the construction of the dam at Hales Bar.

CAPT. THEO. A. BINGHAM'S PRECISE LEVELS OF 1895.

This line of levels is worthy of detailed mention because in it a high degree of precision was attained, and because also, historically as well as geographically, it forms one of the most important lines in the level net in the Tennessee Valley. Starting at Corinth, Miss., the line followed the railroad for a distance of 41 miles, by way of Riverton Junction to Riverton, Ala.; from this point one line extended down the Tennessee River by way of Colbert Shoals Canal to a point 4 miles below Pittsburg Landing, Tenn., a distance of 35 miles; the other line extended for 28 miles from Riverton Junction to Florence, Ala., by way of Tusculumbia, Ala., with a side line 1 mile long from Prides Station to the Tennessee River; it crossed the river over the railroad bridge at Florence and continued along the north side of the river following the old Muscle Shoals Canal to a mile above Nances Reef, where it crossed to the south bank, which it followed to Decatur, Ala., a total distance of 51 miles.

In all, Captain Bingham's lines covered 165 miles, 72 of which were along railroads and 93 along the Tennessee River. The field work was in the immediate charge of Assistant Engineer O. W. Ferguson, who previously had considerable experience in precise leveling. His parties were equipped with Kern precise levels and rods loaned by the Mississippi River Commission. A total of 61 permanent bench marks were set, consisting of copper bolts leaded into ledges of rock, boulders, or masonry, descriptions and elevations of which are published in the Annual Report of the Chief of Engineers for 1896, Part III, pages 1961-1970.

The initial elevation was derived from bench marks V and W established by the Coast and Geodetic Survey at Corinth, Miss., as part of their 1889 survey from Mobile, Ala., to Odin, Ill. These bench marks had been connected also with U. S. P. B. M. "Memphis" of the Mississippi River Commission through a Coast Survey precise-level line run in 1890-91. The differences in elevation so introduced caused Captain Bingham to adjust the elevations of these two bench marks so as to refer to preliminary mean Gulf level of the Mississippi River Commission. (Report of Chief of Engineers, 1896, p. 1957.) This datum had been derived from a tide gauge established by that commission at Biloxi, Miss., by taking the mean of readings from June to September, 1882. (Report of Chief of Engineers, 1894, p. 2795.) It will be obvious that this period of tide gauge readings was entirely too short to establish mean Gulf level with any degree of approximation, and it may be stated here that already in 1894 it was known that the "preliminary mean Gulf level" derived by the commission as above stated was 0.708 foot higher than the mean Gulf level deduced from the self-registering tide gauge at Port Eads, La., which was established in 1876 and had a much longer period of observation.

However, it will be plain from the foregoing that Captain Bingham's line of levels did start from an initial elevation which referred to preliminary mean Gulf level datum, and that therefore all his bench marks in the Tennessee River Valley naturally were considered to refer to that datum. At any rate, the reports and correspondence of this department, in so far as they have come to the writer's attention, all seem to be agreed on that point.

In 1901 an error of 1 meter in Captain Bingham's line, at a point between Iuka and Burnsville, Miss., was brought to light when the line was rerun that year by the Coast and Geodetic Survey. This error alone causes the elevations of the Bingham survey to be 3.28 feet lower than those of the preliminary mean Gulf datum of the commission.

In the fourth general adjustment of the precise level net in the United States made by the Coast and Geodetic Survey in 1912 (see their Special Publication No. 18), the elevations of bench marks V and W were determined to be 0.777 foot higher than the values adopted by Captain Bingham, making the total correction to the Bingham levels about 4.06 feet, by which amount the bench mark elevations are too low with respect to mean sea-level elevations.

Actually, the difference in elevation between the Bingham and Coast and Geodetic Survey levels as determined at bench marks of the Bingham survey along the Tennessee River, varies from 4.055 feet at P. B. M. No. 61 at Pittsburg Landing, Tenn., to 4.065 feet at P. B. M. No. 50 at Decatur, Ala.

All construction levels at the Wilson Dam are based on the Bingham datum. According to a statement by Col. W. J. Barden to the district engineer at Chattanooga under date of March 24, 1921, the difference between the bench mark elevations used

at the dam and those of the Coast and Geodetic Survey in that locality is 4.059 feet, by which amount the latter are higher.

The datum was used in the survey of the Tennessee River made in 1909 from Brown's Ferry to the mouth of the river; also in the survey made in 1913-14 from Decatur to Browns Island. Above Decatur the datum plane used in this survey appears to be in error.

MEAN SEA-LEVEL DATUM.

Mean sea level, or mean tide, has been determined by the Coast and Geodetic Survey, the Mississippi River Commission, and possibly by other Federal and State offices, at various points along the coasts, and is assumed to be at the same elevation on the open coasts of the Atlantic Ocean, the Gulf of Mexico, and the Pacific Ocean. The Superintendent of the Coast and Geodetic Survey in a letter to the district engineer at Chattanooga, dated July 13, 1921, states that while this assumption may not be exactly true, it has proved to be so within quite narrow limits.

With the growth of the net of precise level lines, it was found necessary from time to time to distribute the small errors of closure in the level circuits by means of so-called adjustments. The last one, known as the fourth general adjustment, was made in 1912, and the resulting elevations of all precise level bench marks in the United States were published in Special Publication No. 18 of the Coast and Geodetic Survey. In it are found the adjusted elevations of about 275 bench marks in the drainage basin of the Tennessee River.

The location of these bench marks is usually along railroads. The more important circuits are:

(1) Following the Nashville, Chattanooga & St. Louis Railway from Chattanooga and paralleling the Tennessee River in a general downstream direction by way of Bridgeport, Stevenson, Huntsville, Decatur, Tusculumbia, Iuka, to Corinth, Miss.; also from Tusculumbia down the river to Pittsburg Landing, Tenn.

(2) Following the Queen & Crescent route from Chattanooga by way of Dayton, Harriman, and up the Emory River; also from Harriman via Clinton to Knoxville.

(3) Following the Southern Railway from Chattanooga by way of Cleveland, Athens, and Loudon, to Knoxville, thence via Morristown and along the French Broad River to Asheville.

It will be noted that the two lines between Chattanooga and Knoxville parallel the Tennessee River on opposite sides nearly all of the way, and that in general the precise levels described cover two-thirds of the length of the Tennessee River Valley, while a number of other lines run by the United States Geological Survey and connecting with the Coast Survey lines cover parts of the drainage basins of several of the larger tributaries.

In the course of the surveys made by this office during the spring and summer of 1921, it was found that several bench marks along the Nashville, Chattanooga & St. Louis Railway had been destroyed when that railroad was relocated and regraded some years ago. With these exceptions, it will be noted that a comprehensive system of accurate bench marks referred to mean sea level are scattered over the major part of the Tennessee River Basin.

The later quadrangles of the topographic map of this region published by the United States Geological Survey are based on this datum. Some of the earlier quadrangles were made before the precise level lines had been run, and the contours shown were based on barometric data differing from mean sea level elevations by as much as 30 and 40 feet. Until 1921 the mean sea level datum had not been made use of in any surveys or construction operations of the Engineer Department on the Tennessee River.

THE 12.83-FOOT CORRECTION.

This correction, which rests on an erroneous premise, has caused so much confusion in the work of this district and has had so wide application that it has here been deemed desirable to clearly define its status.

The origin of the 12.83-foot correction is contained in a statement by Mr. J. E. Hall, surveyor, in a report on the "Survey of the Tennessee River between Shellmound and Browns Island," dated Chattanooga, October 31, 1900, and published in House Document 50, Fifty-seventh Congress, first session, page 63, as follows:

"The plane of reference for the levels was transmitted from the Chattanooga gauge by the survey of 1891, assuming the zero of this gauge to be 630.64 feet above sea level. * * * On reaching Decatur with the survey this elevation was compared with a precise level bench mark established in 1895 by Mr. O. W. Ferguson. The levels from Chattanooga were found to be 12.834 feet too high."

The elevation of the zero of the gauge here mentioned is in agreement with Engineer Department datum, and according to Mr. Hall's statement, therefore, Engineer Department datum appeared to be 12.834 feet lower than the Bingham datum.

It is important to note that the correction was not made use of for 24 years following its determination, as above set forth. The 1909 survey, which covered the entire river, continued the use of the Engineer Department datum from the head of the river down to Browns Ferry, Ala., and of the Bingham datum from Browns Ferry to the mouth. Not until 1913, when Major Burgess was ordered to make a resurvey of the river from Hales Bar to Browns Island, was it decided to adopt the Bingham datum on that part of the river by applying this correction to the elevations previously established. Later, in the surveys made in 1915, 1916, and 1917 for navigation dams between Hales Bar and Decatur, and on the upper Tennessee River at Caney Creek, the correction was also applied.

This was done in the full belief that its application would reduce elevations based on Engineer Department datum to the Bingham datum. This it failed to do, however, as evidenced by the studies made in this office and as confirmed by Mr. Hooper's leveling operations above referred to. The indications are that the correction should have been 13.911 feet instead of 12.834 feet. Lack of funds did not permit of continuing the check-level lines during 1921 from Widows Bar Dam to Decatur for the purpose of locating the discrepancy, and all that can be stated at this time is that the error amounts to 1.077 feet, that it must have occurred somewhere between Widows Bar and Decatur, and that presumably it was caused by misreading the rod by an even foot. It is highly desirable that this error be located as soon as funds become available for continuing the survey.

The introduction of the 12.83-foot correction in the various surveys mentioned has served to add measurably to the confusion that already existed in the use of the various level datums. This is reflected in the notes appearing on the maps made from the various surveys, the wording of most of which is misleading rather than clarifying. Thus on the flowage survey maps of the Widows Bar and Bellefonte Dams, dated 1916-17, the following is stated: "All elevations refer to the precise level datum used by Captain Bingham in 1895, which corresponds to the elevation of 552.351 for P. B. M. No. 50 at Decatur, Ala." Our investigation discloses that they do not refer to that datum and that although the elevations were intended to correspond with bench mark No. 50, actually no levels were run connecting them with that bench mark, but instead their elevations were obtained from levels connecting with Chattanooga. Had proper connection been made with P. B. M. No. 50 the error of 1 foot, referred to above, would have been disclosed.

On sheet No. 59 of the 1913-14 survey between Hales Bar and Browns Island appears the following note: "All elevations refer to preliminary mean Gulf level of the Mississippi River Commission (see An. Rep. Chf. of Engrs. 1901, p. 2574-5), which is 12.83 feet above datum used on 1909 survey." It will be clear from the preceding remarks that actually the elevations differ by several feet from the Mississippi River Commission preliminary datum.

Again, on the 1909 survey drawings, appears the following note: "Elevations, Chattanooga to Browns Ferry are referred to Gulf level, as assumed from former Engineer Department surveys, which is 12.85 feet below the preliminary mean Gulf level of the Mississippi River Commission. Elevations, Browns Ferry to Riverton are referred to mean Gulf level (Mississippi River Commission)."

It should be stated here, that, all references to the contrary notwithstanding, neither the preliminary nor any other Gulf level datum of the Mississippi River Commission has ever been used in any of the Tennessee River surveys.

PRESENT STATUS OF TENNESSEE RIVER LEVELS.

The net result of the use of the various level datums and corrections as above set forth is that to-day each of the three dams now built or being built on the Tennessee River is based on a different level datum. Hales Bar dam, completed in 1917 was based on the old Engineer Department datum. Wilson Dam elevations are referred to the Bingham datum; and Widows Bar Dam elevations are about 1 foot higher than the latter.

Above Hales Bar Dam and Browns Island, the Engineer Department datum and the erroneous datum caused by the application of the 12.83-foot correction are both in use. Below Browns Island the Bingham datum is the only one used. The status is shown graphically on the accompanying diagram. (Plate No. V.)

It is scarcely necessary to point out that the future planning of dams or other engineering structures on the Tennessee River is likely to be beset with many apprehen-

sions, and may result in costly errors as the result of confusing these planes of reference.

During the field season of 1921-22 all level lines run by parties from this office were referred to mean sea level as established by the Coast and Geodetic Survey, and it is the use of that datum that has enabled me to ascertain the facts and reach the conclusions presented herein. With the knowledge so gained it is hoped that, as additional funds may become available, eventually all elevations shown on former Tennessee River survey maps may be referred to a common datum.

GERARD H. MATTHES,
Assistant Engineer.

APPENDIX D.

MAP MAKING BY COMBINED USE OF AERIAL PHOTOGRAPHS AND GROUND SURVEY METHODS.

Early in the course of the work on the preliminary examination made of this survey in 1920, attention was directed to the possibility of employing the method of aerial photography in connection with the preparation of the additional maps which it was evident would be needed. This led to investigations of this subject in Washington by the district engineer in September, 1920, which were followed by a conference held in this office the following month between the district engineer and representatives from the office of the Chief of Engineers, the Air Service, and the United States Geological Survey, who had given special attention to this form of map making since it was first taken up in this country during the war. All phases of the matter having been duly considered the following report and recommendation on this subject were submitted to the Chief of Engineers on October 28, 1920:

1. In continuation of the investigations begun in Washington, D. C., during my visit there last month there has been held in this office a conference on the above subject between the district engineer and representatives of the office of the Chief of Engineers, the Chief of Air Service, and the United States Geological Survey.

2. The proposed survey of the Tennessee River and its tributaries authorized by the last river and harbor bill will include studies of floods, drainage, industrial and mineral resources, and existing or possible hydroelectric development in so far as these may be expected to have a reasonable bearing on the question of navigation in this region, and the basis of all these studies must be a sufficiently accurate map of the territory under consideration. The Engineer Department has made from time to time accurate maps of the Tennessee River from its mouth to its headwaters and also of some of its most important tributaries. These maps, however, are essentially channel surveys and include, as a rule, only the section along the rivers between the tops of the banks and in the comparatively few instances where more topography is given it is not certain that this extends as far away from the river as will be necessary for the purposes of this survey. The maps of the Muscle Shoals section, are, perhaps, the only exception to this rule. The United States Geological Survey has issued topographical sheets for a large part of this area, but with a few exceptions these are on a scale of approximately 2 miles to the inch with 100 foot contours, which is too small for our needs. In addition, these small-scale maps are known to be too inaccurate for the studies of this extensive survey. There exists a few maps made from other surveys, but so far as these are known to this office they neither contain sufficient data nor are they of sufficient reliability.

3. It therefore seems to be evident that the first duty to be performed in connection with this survey will be the preparation of accurate maps of the territory under consideration with sufficient detail to meet the requirements of the different classes of studies indicated above. It will probably be impossible to tell accurately what area must be covered by this new map until work on its preparation has been under way for some time, but it seems reasonable to assume that this area will not be far from 2,000 square miles.

4. The first object of the conference which has just been held here was to decide whether aerial photography could be used to advantage in the mapping of so large an area in this region. This question was approached from the following points of view:

(1) Are the methods of aerial photography suited to the conditions which would obtain here? (2) Is the personnel and equipment necessary available? (3) How would the cost of the method of aerial photography compare with the standard methods of making the required map by ground survey? (4) How does the accuracy of the two methods compare? (5) The speed? (6) The amount of detail?

5. In order to obtain definite answers to the questions listed above, it was recognized that further discussion should be based on some reasonably tangible set of specifications which must be met in this connection. With this point in view, the following list of requirements was prepared solely as a basis for further discussion. It is believed that these are reasonably close to what will eventually be prescribed, but their final acceptance in all detail is not at this time essential.

REQUIREMENTS OF MAP FOR TENNESSEE RIVER SURVEY.

It is estimated that about 2,000 linear miles of river valley will be mapped, varying in width from one-half mile to several miles, with an average of 1 mile. Total area to be covered by topography has been taken at 2,000 square miles. The field scale will be 1: 21,120 (3 inches=1 mile), and the publication scale 1: 24,000 (2,000 feet=1 inch). Contour interval will be 5 feet in the valley bottoms and in all level areas likely to form part of a proposed reservoir site. On hillsides the interval will be 10 feet. Limit of error in elevations used to determine contours to be one-fifth of contour interval, and maximum allowable error of location to be 0.01 inch on scale of publication.

The completed map will show the following: All water courses, and, in the case of large rivers that are navigable or are capable of being made navigable, the configuration of each bank, islands, and shoals; all railroads, highways and roads, pole lines for power transmission, telephone and telegraph; bridges, locks and dams, buildings, and important fence lines; the classification of lands as (1) woodland, (2) pasture lands, (3) cultivable land, (4) waste land, and the outlines of all wooded areas, by means of suitable symbols. Area to be covered to include valley bottom and adjacent hillsides and tributary valleys far enough to furnish complete information for making estimates of flowage lands and cubic capacity of reservoirs for the maximum height of dam that may reasonably be selected at any given locality. Where lands are known to be outside of any possible reservoir location, the topography should include so much of the valley bottom and foot of hills as is subject to overflow by greatest recorded flood. Soundings and borings in river channels now navigable or capable of being made navigable, or for exploring the foundations of prospective dam sites, are not considered a part of the program of the mapping operations and are not included in this study.

6. All members of this conference were in strict accord in the opinions and conclusions which were reached relative to the points above listed. These opinions and conclusions may be briefly summarized as follows:

ARE THE METHODS OF AERIAL PHOTOGRAPHY SUITED TO THE CONDITIONS WHICH WOULD OBTAIN HERE?

This is obviously the fundamental question to be considered and all matters bearing on this subject were given most careful and exhaustive consideration. The representatives from the Air Service and the Office of the Chief of Engineers are men who have had extended experience in this class of work, being not only familiar with the theory involved, but also well experienced in the practical application of this theory on widely varying types of terrain. They obtained during this conference a very fair idea of the nature of the terrain most likely to be encountered in the proposed survey and of the problems which could be expected to arise, and, basing their opinions upon this information and a comparison with their previous experience, they agreed without hesitation that the methods of aerial photography were well suited to the conditions which would obtain in this region. Although there is a great amount of heavy relief in the territory to be met, that part which is of interest to this survey lies along the valley floors, it is comparatively level, and is therefore admirably suited for aerial photography.

IS THE PERSONNEL AND EQUIPMENT NECESSARY AVAILABLE?

The personnel required for the complete operation of that part of the survey which pertains to aerial photography may be divided roughly into (1) that which operates the planes and takes the pictures, (2) that which develops the negatives and produces the photograph which the draftsman will use, (3) the drafting force which builds up the map.

With respect to the first class, this personnel would be furnished by the Air Service, and the representatives of that service stated that the personnel needed for the work contemplated could be made available as required. With respect to the second class, which is charged with the duty of developing the negative and preparing a print which may be used by the draftsman, this, under certain conditions, may require

very specially trained men. These conditions are those which follow from the use of the tri-lens camera, which require the process known as transformation to make a photograph which can be used by the ordinary draftsman. The number of men who are able to make this transformation is very strictly limited, and, so far as known to this conference, exists only in the small personnel developed in the office of the Chief of Engineers during the last two years, with one additional man now in the employ of the Geological Survey. If the tri-lens camera should be used here, it will be essential that at least one of these specially trained men be put at the service of this office for the period covered by the duration of this work. The third class requires draftsmen who are trained in taking the proper information from a photograph and transferring it to a map. This work is within the ability of any average draftsman, but best results are obtained when the draftsman is experienced in this particular form of work. A certain number of experienced men will probably be available and others can undoubtedly be trained in a short time. For the rest of the work the operations and personnel required are those which are standard in the preparation of maps.

With respect to the matter of equipment, the special equipment needed for aerial photography consists of the airplanes with their photographic and other accessories and the photographic laboratory for the developing of negatives and of printing and transforming of photographs. The Air Service is prepared to furnish the airplanes with all necessary accessories, also the apparatus of all kinds needed for the developing and printing of photographs. The Engineer Department would be expected to provide the apparatus necessary for transforming and should provide the necessary work and drafting rooms. All other equipment needed is standard in ordinary mapping operations and would be obtained in the usual way. It is understood that the transforming equipment is available in the office of the Chief of Engineers and that the furnishing of personnel, equipment, etc., by the Air Service is done in accordance with the provisions of paragraph 448½ of the Army Regulations.

HOW WOULD THE COST OF THE METHOD OF AERIAL PHOTOGRAPHY COMPARE WITH THE STANDARD METHODS OF MAKING THE REQUIRED MAP BY GOVERNMENT SURVEY?

In order to make a proper comparison of costs between ground and aerial surveys, certain assumptions as to limits of error, etc., were made in order to obtain positive results. It is believed that these assumptions are very close to what will finally be adopted as standard for this survey, but the final acceptance of these assumptions is not expected at this time. Under these assumptions, then, two sets of estimated costs were prepared, one for the map without aerial photography and the other with it. This comparison is as follows:

MAPPING WITHOUT AERIAL PHOTOGRAPHY.

Horizontal control.—Ground survey to utilize existing triangulation net and existing primary traverses, and to extend both triangulation and traverses and connect same with each other.

Field work, cost per square mile. . . . \$8

Vertical control.—Ground survey to utilize existing Coast and Geodetic Survey precise spirit level lines and Geological Survey primary level lines, extending these by running circuits, preferably over highways or railroads paralleling river courses and crossing the latter at intervals of from 15 to 25 miles, setting permanent bench marks every 3 miles; limit of error of closure of circuits, in feet, to be $0.05 \sqrt{\text{distance in miles}}$.

MAPPING WITH AERIAL PHOTOGRAPHY.

Horizontal control.—Same as for mapping without aerial photography, except that the extension of both traverses and triangulation will be made with special reference to the needs of the aerial photographic work. The modifications so required will not increase the cost; they will, if anything, reduce the cost.

Field work, cost per square mile. . . . \$8

Vertical control.—Same as for surveys without aerial photography.

Field work, cost per square mile.... \$3

Topography.—Ground survey topographer equipped with plane table to run traverses along all principal roads and watercourses; to locate all cultural details, including pole lines for power transmission, telephone and telegraph, bridges, locks and dams, buildings, and principal fence lines; to sketch contours and determine all contour crossings at streams; to classify lands and show boundaries of wooded areas.

Field work, cost per square mile.... \$75

Office work.—On part of ground survey to include adjustment of triangulation observations and level circuits; computations of traverses and connection of same with triangulation system; inking and lettering field sheets.

Office cost, per square mile..... \$3

Field work, cost per square mile.... \$3

Aerial photography.—To be taken by Air Service, using its personnel and equipment free of charge. (See par. 448, Army Regulations.) Completed photographs to be delivered to Engineer Corps. Actual cost to Air Service, \$2 per square mile, for which no charge will be made to Engineer Department.

Compilation of base map from aerial photographic data.

Office cost per square mile..... \$2

Topography.—Ground survey topographer equipped with plane table to be furnished with copies of aerial photographs and with base maps compiled from aerial photographs, which will show watercourses and cultural details enumerated under "Mapping without aerial photography," and also, to a large extent, the character of lands as regards classification, the topographer to supplement the foregoing in so far as the data derived from the photographs may be indistinct or in doubt. He is to sketch contours and determine contour crossings at streams.

Field work, cost per square mile.... \$50

Office work.—Same as for survey without aerial photography.

Office cost, per square mile..... \$3

Summary of cost.

COST PER SQUARE MILE.	
Control.....	\$11.00
Topography.....	75.00
Office work.....	3.00
Total.....	89.00
Total cost on basis of 2,000 square miles.....	178,000

COST PER SQUARE MILE.	
Control.....	\$11.00
Topography.....	50.00
Office work.....	5.50
Total.....	66.50
Total cost on basis of 2,000 square miles.....	133,000

The above figures include all necessary cost of immediate direction and supervision but no general overhead costs, which would be about the same in either case.

For printing map on scale of publication by photolithographic or zinc etching process in three colors, add \$1 to total estimated cost per square mile in each case.

From the above tabulation it will be evident that the use of aerial photography will decrease the cost of the map prepared without the use of this method by about 25 per cent, or, stated the other way round, to discard the use of aerial photography will increase the cost of the work by about 33½ per cent. On the basis of a survey of 2,000 square miles the total saving will be about \$45,000. This would seem to point to the conclusion that from a financial standpoint the use of aerial photography is very much to be desired.

HOW DOES THE ACCURACY OF THE TWO METHODS COMPARE?

To the engineer unfamiliar with the use of aerial photography it seems obvious that a photograph which ordinarily includes every detail, large and small, is more accurate than a map prepared by a man in the field, which shows only what his judgment tells

him should be included in his work and whose vision is limited by his position on the ground. Questions, however, arise as to the elements of error introduced by possible distortions due to the photographic lens, by the plate being inclined at some angle at the instant of exposure, by the misinterpretation of objects in the photograph, by the varying elevations of the plane carrying the photographic apparatus, by the varying elevation of the ground beneath him, and by the possible concealment of such things as small streams or other features by dense foliage, and the like. The efforts of the map sections of the Engineer Department and of the Air Service have been largely directed during the two years of experimental work toward the elimination or reduction of errors from these or other sources. Within the past 12 months aerial surveys have been made for the United States Geological Survey where it was possible to compare the results thus obtained with the best standards of that department. While all errors have not as yet been eliminated completely, this comparison has shown that by aerial photography there can be produced with a reasonable degree of certainty a result which will compare favorably with the best standards obtaining in the United States Geological Survey. It is believed that the standards of this survey are in every respect adequate for the proposed survey of the Tennessee River and that therefore the degree of accuracy which can be obtained by aerial photography will be in every way acceptable in this case.

SPEED.

In this connection it should be mentioned that the Air Service figures that it should take them approximately three months of average good flying weather to take the necessary photographs of the estimated 2,000 square miles in this territory. Once these photographs are taken there remains the large volume of office work necessary to pass from photographs to maps without contours and then follows the period necessary for plane-table men to go into the field with these maps and put on contours. It follows that it is theoretically possible by increasing sufficiently the number of plane-table parties in the field to hasten very materially the final completion of the finished map. Present indications are that plane-table men competent for this work will not be found easily, and, judging by the present experience of the United States Geological Survey, it would seem that it might be difficult to put into the field more than 10 parties competent to do this class of work. It is unnecessary to add that every effort would naturally be made to increase this number.

In the study of the relative costs of ground and aerial survey, it appears that the item of cost is in very large measure a function of time and that the reduction in cost shown in the tabulation above results in large measure from corresponding reduction in time. In other words, the cost studies also indicate that the speed of the work is increased by about 25 per cent by using aerial photography.

THE AMOUNT OF DETAIL.

It will be obvious that a photograph contains record of practically every detail which exists on the ground, and that this detail is transferred from the photograph to the map in an office where as much time can be spent in this manner as may be desired. From this it would seem to follow that the amount of detail put on the finished map is governed only by the regulations established in the drafting room as to what should be transferred. In this respect, it would seem that the ground surveys are not to be compared with aerial surveys. Furthermore, the photographs obtained by aerial survey would, presumably, be kept in permanent files and if the data first transferred should prove to be insufficient, it would be possible to extend this to any degree desired, simply by consulting the photographs and without the necessity of having to send men back into the field to get information which had been omitted. Such cases might readily arise where a map was drawn from the photograph solely with the view of showing ordinary topographical features when no new work of any kind was contemplated. Later, more detailed information might be needed in connection with a proposed reservoir or dam site or industrial development where data would be called for which had not previously been shown on the map. In such a case instead of sending parties back into the field for new surveys, an examination of the photograph would, in most instances, give all information needed.

7. To summarize, the report on the preliminary examination and survey of the Tennessee River has progressed to the point where it seems probable that an extensive survey of this basin will be recommended. A practically new map of something like 2,000 square miles would be called for, and the question now before this office is how should this map be made. Formerly there existed only the long-standard

methods of ground survey, but now the method of aerial photography has attained such prominence that it can not be ignored. All further plans touching on personnel, equipment, costs, etc., will be directly affected by the methods employed, and it therefore seems proper that a decision should now be made as to whether or not aerial photography should be used in this connection, a decision which can obviously be made only by the Chief of Engineers. A very careful investigation of this matter has therefore been made, and I have in the foregoing laid this matter before him in, I hope, sufficient detail to enable him to feel that he is justified in giving a decision on this point. It was found impossible to avoid touching upon some other matters which will necessarily have to be reviewed later by the Chief of Engineers, but at this time a decision is asked only on the one question, whether our plans shall include the use of aerial photography?

8. This has been the subject of careful study and much thought on my part and I recommend that aerial photography be used in connection with the proposed survey of the Tennessee River to the fullest extent consistent with the best interests of the Government.

9. In making the foregoing study this matter was brought to the attention of Col. C. O. Sherrill, Corps of Engineers, chairman of the committee on coordination of the Board of Surveys and Maps; and Mr. C. H. Birdseye, of the same committee and board, has been freely consulted. It is believed that this method of procedure and this recommendation follow closely the wishes of the President of the United States as expressed in the Executive order dated December 30, 1919, which created the Board of Surveys and Maps of the Federal Government.

No further action was taken in this matter until after the submission of the report on the preliminary examination and the survey in January, 1921. Then, while awaiting the action of the Chief of Engineers on this report, this subject was again approached in a tentative way with representatives of the Air Service with a view of having ready a plan for cooperation in the event that the action of the Chief of Engineers should be such as to permit this line of procedure. The result of this informal action was the formulation of the following plan which it was proposed to submit to the proper authorities for official consideration when events should justify such a course:

1. The following will be the basis of all work done in cooperation between the Air Service and the district engineer, United States Engineer Department, Chattanooga, Tenn., in the preparation of maps of the basin of the Tennessee River:

(a) The Air Service will, without expense to the Engineer Department, furnish all personnel and all material, supplies, etc., necessary to take aerial photographs and will furnish the Engineer Office with finished photographs ready for the preparation of the desired maps.

(b) The Engineer Office will provide the Air Service with suitable office space and equipment for the period of this cooperation.

(c) The Air Service will provide an experienced officer of that service to report directly to the district engineer, and this officer will have immediate control of all the personnel, activities, etc., of the forces detailed by the Air Service on this work. Within the limits imposed by the weather, the limitations of the apparatus used, etc., the photographs will be taken at the times, places, and in the numbers prescribed by the district engineer. In this connection it is understood that every effort will be made to facilitate and expedite the work of the Air Service which will not be detrimental to the interests of the survey of the river as a whole.

(d) Where there is any choice in the character of equipment to be used, single lens or trilens cameras, for example, that type of equipment will be used which experience shall show is best suited to the needs of the survey.

(e) The necessary ground-survey control will be established by the Engineer Office.

The funds made available when further work on the survey was authorized in May, 1921, were much smaller than what was necessary to start map-making operations on the scale which had been anticipated up to that time, and for this reason it did not seem advisable to obtain the formal approval for this comprehensive plan of cooperation in all its details. However, the use of aerial photography was possible and desirable and was therefore undertaken. It was actually carried out on a less ambitious scale, but followed the lines tentatively agreed upon with such modifications of minor importance as were obviously best adapted to the comparatively limited program.

Two officers of the Air Service arrived in this city on August 7, in a De Havilland plane carrying a K-1 camera and all apparatus necessary for taking aerial photographs and they took their first photographs on August 9. They remained in this city on this work until October 3, except for an absence of seven days in September while engaged on a wholly independent project in the western part of this State. A few days suitable for this work were lost due to the necessity of making minor repairs to

their equipment or similar unimportant causes. With this exception, flights were made on every day suitable for this work. It should be borne in mind that such a suitable day is not simply a clear day but it must also be practically a cloudless one. The number of such days that occurred here during their seven weeks' stay was not above average and it is believed that about as much work of this character as was done in this case could be done in this region in the same length of time at any season of the year. Exposed films were sent to Langley Field, Va., for development and printing. It was found that once or twice the photographic apparatus would get out of order in such a way that the fact became apparent only upon examination of the developed negative. In such cases the fact would not be known here until after the film had gone to Langley Field, there developed and notice of the trouble was sent from the field to this city. This covered a period of several days during which more work was sometimes done with the apparatus out of order and this additional work was lost. Had operations been carried on on the larger scale at first contemplated the developing and printing would have been done in this city and the results of one day's work would have been known before the next day's work was begun, such errors as these would then have been eliminated and even larger results would have been obtained in the available time than were actually obtained under existing conditions.

The Air Service officers were authorized to take photographs covering an area of about 500 square miles. After careful study the area selected was that following the Tennessee River from the head above Knoxville to a point a few miles below Chattanooga; also a narrow strip following the Hiwassee River from its mouth upstream a distance of about 20 miles. This gave a total area having a length of little more than 200 miles and an average width just under $2\frac{1}{2}$ miles. Photographs were taken successfully on 11 days and a total of 1,048 views were taken with the K-1 camera. One hundred and ninety-four of these were taken over the city of Chattanooga, a large part of the city lying within the flood plane of the Tennessee River, 65 were obscured by clouds or otherwise unserviceable, while the remaining 789 were divided into 44 strips or flights which covered the area described. Photographing was done from an elevation of 12,500 feet; each photograph is 7 by 9 inches, showing an area of approximately $3\frac{1}{4}$ square miles, on a scale of 1:15,000. It was planned that successive photographs should have an overlap of 60 per cent and adjacent flights an overlap of about 15 per cent. Actually the average overlap of successive photographs is under 50 per cent while the overlap of adjacent flights is irregular, though always sufficient, due to additional flights being made from time to time to fill in gaps between flights which were intended to overlap, but did not, due to unavoidable drift of the plane in light and variable air currents.

An Engineer officer on duty on aerial mapping at McCook Field, Dayton, Ohio, was assigned to duty in this office temporarily for about three weeks during the time these photographs were being taken and rendered valuable assistance in the matter of coordinating the work of the aviators with the needs of this office, overseeing a variety of details, etc. At his request a trilens camera was sent here from McCook Field and several series of photographs were taken with it, the chief purpose being to use these photographs to orient series of K-1 photographs and adjoining sections of the reduced channel survey sheets of Tennessee River mentioned below. Unfortunately, due to mechanical troubles with this apparatus, a large number of the photographs so taken were defective, but enough serviceable photographs were obtained to accomplish, in several instances, the orientation desired. The tests made were sufficient to prove the value of this method of orientation, for the results obtained both facilitated the adjustment of K-1 photographs to the channel survey sheets and demonstrated the accuracy with which maps may be prepared. It is believed that maps prepared in this way will be entirely adequate in accuracy for the immediate needs of future investigations of this kind and to serve as parts of future standard topographic maps on scale of 1:62,500.

As a result of previous experience in aerial mapping it had been decided that the final maps prepared from the photographs taken for this survey should be built up around an adequate system of triangulation stations located in the area to be mapped and sufficiently numerous to insure a high degree of accuracy. When the time came, however, to start this part of the work further study was made of existing plats of this part of the river prepared in connection with former studies of proposed improvements for navigation in this region. These plats covered the entire section of the Tennessee River now under consideration with bank lines located throughout by an accurate traverse system. It was obvious that a traverse control is not as accurate as the control that can be secured by a triangulation system. On the other hand, when full consideration was given to the purposes of the present survey and to all the uses which could properly be made of the forthcoming map, it became evident that neither these purposes nor possible uses would justify the expenditure of time

and money necessary to establish the proposed triangulation system. Accordingly existing channel plats were reduced photographically to the scale of the new map (1:20,000) at the Engineer reproduction plant at Washington Barracks, D. C., and it was planned to combine these and use them as the control for the new map. The Engineer detachment at McCook Field being engaged on experimental work of almost exactly this type and with a view to husbanding the small funds available for the Tennessee River survey it was decided to have the work of preparing the flat map (one without contours) from the channel survey and the photographs (both K-1 and trilens) done there as part of this experimental work. The necessary approval of the other interested authorities having been secured, the aerial photographs and the photographic reductions of the former channel survey were sent to this detachment at McCook Field.

A knowledge of elevations, or the proper location of contours, is essential to the needs of the present survey and from the outset it had been kept in mind that when these flat maps were finished it would be necessary for survey parties working in the field to add such contours as were needed. In addition to the general contour map special large-scale contour maps would be needed for the various sites where power navigation dams might be considered. These sites had been selected with care by field inspection in June, 1921, and simultaneously with the arrival of the aviators in August a survey party was put in the field to begin work on these dam sites. These surveys were made in the way usual for high grade plane table work on a scale of 1:2,400 with 2-foot contours. In this way, in addition to obtaining special maps of possible dam sites, the field party was well trained for the work of adding contours to the flat general maps.

The data for the flat maps was sent to McCook Field early in October. By the end of that month it had developed that while theoretically the work of preparing these maps could be done there, practically the routine work of Engineer detachment, which had to take precedence, was so great that the work for this office could not be completed in time for the preparation of the report to the Chief of Engineers which otherwise could be submitted early in 1922. This necessitated a thorough revision of our plans, and this led to another study of the matter which brought into prominence the following points: The primary use which will be made of this general map will be to determine with reasonable accuracy the nature and extent of the territory which may be flooded by the pools formed by any power navigation dam proposed in this section, also the territory which may be appreciably damaged by increased height or duration of floods resulting from the construction of such a dam. In no case will the territory which need be considered extend higher than 60 feet above the low-water mark. Numerous checks were made by measuring in the field the distance between two objects which were well defined in the photographs and which were not more than 60 feet above low water.

This clearly established the fact that such a measurement made on the ground with instruments and by the methods customarily employed for such surveys can not be plotted more accurately to a scale of 1:15,000 than it is already shown on these photographs. On most of the photographs, which are only slightly inclined from the horizontal plane, there is no appreciable distortion of scale or angles in the areas below this elevation. The photographs show clearly and with a wealth of detail the channel lines of the river, roads, fences, woods, cultivated lands, etc., and below the 60-foot elevation these are shown with an accuracy which on a scale of 1:15,000 can not be surpassed by the most careful measurements on the ground. Obviously an area can be measured on a map with no higher degree of accuracy than its boundaries are there shown, and since in this case and on this scale the boundaries shown photographically are as accurate as if they had first been measured on the ground and then plotted, these photographs give areas with acceptable accuracy. Finally, since all photographs have ample overlap, an area can be measured which extends over any number of views. This can be done by measuring the part which falls on one view and is bounded by a line drawn between two well-defined objects which are common to this view and the next adjacent. Measurement is begun on the second photograph at this common boundary and carried to a similar boundary common to the second and third views, and so on.

The overflowed areas, which are the only ones to be measured in this case, extend for the most part in a long narrow belt on each side of the river, and 1 square mile of such an area could easily extend over 20 different views. It seems clear that instead of measuring so small an area in so many fractional parts and then adding the totals it would be easier and more accurate to first combine all the parts and then measure the area as a whole. This, then, indicated a logical and satisfactory method of procedure. The photographs themselves were sent to the field party, and were used there in every respect as plane table sheets on which was given in complete detail and to scale (below

the 60-foot elevation) every natural feature and cultural detail, except such as were dependent upon differences of elevation. Preceding channel surveys had left an ample chain of bench marks. Starting with one of these and the view on which it is shown, the elevation of the points needed to define contours are quickly determined, the contours are drawn on the photographs, and the levels carried to the next bench mark with a practically level surface—that is, the river between rapids or shoals—being for the most part always at hand for a check.

When the penciled contoured photographs are received in the drafting room, contours, bank lines, small streams, and such cultural details as are desired on the finished map are brought out carefully and clearly with ink, and with this reinforcement no great difficulty is found in tracing them on ordinary tracing cloth. In order to avoid errors which might appear, due to the distortion of the photographs around the edges, contouring is done as much as possible only in the center of each view. However, flights had to be made in straight lines, and the river is winding, so that at times work has to be done near the edges.

In joining successive photographs the Tennessee River is the guide. Although contours may appear only on the middle third of the first view, the bank lines of all the river shown on that view are carefully traced. The succeeding view of the same flight with its 40 per cent to 60 per cent overlap is then adjusted under the tracing cloth, so that its bank lines throughout this lap coincide with those traced from the preceding photographs; the bank lines are continued across the second view; the third view is adjusted, and so on. As just stated, errors of distortion along the river are usually very small, but when they are visible they occur at different places on these adjacent photographs and a fairly accurate position is not hard to determine.

It will be noted that the original plans for this work contemplated the use as a control of existing channel survey sheets prepared by standard ground survey methods and having an accuracy in accordance with standard requirements. These sheets were to be tested for still greater accuracy by the use of the trilems and to some extent the K-1 photographs and all detail except contours was to be added from these photographs. As actually carried out the use of the trilems photographs resulted in the detection of measureable errors in the original ground survey sheets as also did the use of the K-1 photographs. The most probable explanation of this fact seems to be as follows: The ground survey was based on a traverse system wherein the distance and bearing from station to station was measured to within the required limit of error. With this as a framework, bank lines were sketched in, doubtless by offsets, to numerous salient features but for the rest by eye. The traverse does not appear on the finished sheets so when a check is to be made, a distance is measured between two points selected at random along the river bank and these in general fall at points which were not located by offsets in the ground survey. For the most part the differences in these distances as measured on the ground survey sheets and those based on aerial photographs are small enough to be accounted for as differences in the personal equation either in plotting when the maps were made or in scaling from the finished sheets. Occasionally, however, a discrepancy appears which can not be so explained and then a comparison is made between the ground survey sheet and the corresponding photograph. In each case this has shown a perceptible difference between the form and degree of curvature of the bank as shown by the photograph and the ground survey which has been sufficient to account for the excessive discrepancy. In such a case it seems evident that the photograph is correct and that in the ground survey the section appeared to the sketcher foreshortened and that for this or some other reason he introduced an error into his work. The following table shows some of the principal check measurements on which the foregoing statements are based. It will be noted that these vary in length from about a half a mile up to about three miles and a half. These longer measurements extend over a number of photographs and indicate that the method above described of adjusting adjacent photographs gives a very good degree of accuracy.

TABLE 3.—*Check distances used in construction of topographic map of Tennessee River Valley of 1921-22.*

Description of distances.	1909 survey; scale, 1:6,000.	1921-22 topographic map; scale, 1:15,000.	Adjusted map; scale, 1:20,000.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Out to out of north and south loops near Post Oak Island.....	14,630	14,375	.....
Width of Post Oak Island.....	2,420	2,450	.....
Length of Post Oak Island.....	6,500	6,560	.....
Across neck west of Post Oak Island.....	3,800	3,750	.....
Across neck west of Post Oak Island, including island and river.....	7,520	7,438	.....
Foot of Post Oak Island to foot of Prater Island.....	18,530	18,562	.....
Across neck at Keller Bend.....	4,080	4,125	.....
Across widest part of Keller Bend.....	4,890	4,850	.....
Out to out, bend at Prater Island to bend west of Cox Island.....	17,700	17,750	.....
Perpendicular to Louisville Ferry.....	8,590	8,588	.....
Foot of Prater Island to point A (near Concord).....	20,375	20,375	20,167
Across bend south of Concord, A to B.....	7,610	7,460	.....
Across neck south of Concord, out to out.....	3,880	3,850	3,820
Across neck south of Concord, out to out, inside to inside.....	2,450	2,440	2,250
Point O near Concord, to point P, near Chattanooga Island.....	19,770	19,900	19,900
Point P to Louisville Landing.....	30,730	30,750	30,750
Foot of Prater Island to Louisville Landing.....	11,270	11,250	11,310
Foot of Prater Island to head of upper Coulter Island.....	.....	33,600	33,400
Foot of Cox Island to head of upper Coulter Island.....	.....	26,500	26,200
Foot of Cox Island to point Q in bend west of island.....	.....	7,370	7,370
Perpendicular D (from O south).....	.....	11,490	11,600
Coulter Shoals, point M to Louisville Landing.....	.....	38,400	38,200
Point O to Louisville Landing.....	.....	30,300	30,200

NOTE.—Second column contains distances scaled from lithographic tracings of survey of Tennessee River made in 1909; third column contains same distances scaled on new topographic map traced from aerial photographs; fourth column contains same distances scaled on map constructed at McCook Field from aerial photographs with control derived from 1909 survey and trilens photographs.

It is to be remembered that the present survey is one which is very long in one direction and comparatively short in the other. Every effort is made to make the long dimension accurate and as a rule special attention to accuracy in the other dimension is not important. It is possible that if these areas were nearly square more difficulty would be found in getting the same degree of accuracy for long distances measured at right angles to each other. So far no test of this kind has been possible, but it is hoped that in the future work on this survey long circuits can be brought together at points distant from a common origin and that then more information can be obtained relative to the absolute accuracy of the locations on all points in areas of approximately the same extent in all directions. The tests of the trilens photographs have established its value as an aid to control and by its use in the future it is believed that the degree of accuracy obtained from photographs alone will be materially increased. Existing ground surveys will be used as checks in the future wherever possible, but eventually it will be necessary to cover areas as yet unmapped or where existing maps are too inaccurate for use in this way. I am satisfied that in such cases methods above described and still further perfected by future use will be sufficient to produce maps satisfactory for all the purposes of this survey and also of recognized value for general use.

The work of the Air Service in connection with photographing the upper Tennessee Valley was done as part of the regulation training of that branch and was paid for out of the funds available for that purpose. The actual cost to that service was \$3,400. The travel expenses involved in various inspections and in other incidentals connected with this work was \$508 paid by survey funds, making the total actual cost of the photographs of the 500 square miles \$3,908. The cost of contouring is best stated by comparing it with the total length of main river and tributaries along which contours have been run. On March 1 this was about \$32 per mile. This included the time spent in organizing parties and in training them for this special kind of work. It is expected that this cost can be reduced if the present trained force does not have to be disbanded. The actual work of taking the photographs under existing conditions was to some extent experimental. In future work of this kind it is expected to take full advantage of this experience and material reduction should be made in costs, particularly if this work is done on a more extensive scale.

In conclusion, it is desired to state that, while the use of aerial photography in connection with the map work of this survey has introduced some unexpected puzzles and problems, the results to date are more favorable than it was anticipated would be the case when this method was adopted. It is believed that the maps prepared in this way will be found to be adequate for all the purposes of this survey and that if more accurate maps of this region are needed in the future the data recorded on the photographs on file in this office will prove to be of marked value when used in connection with any system of horizontal control, ground or aerial, that may be established in future to prepare a map of the Tennessee Valley accurate in every detail that can be shown on scale of 4 inches to the mile.

It is strongly recommended that the use of aerial photography be continued in the future map work of this survey.

HAROLD C. FISKE,
Major, Corps of Engineers.

APPENDIX E.

SILT DEPOSITS IN THE TENNESSEE RIVER.

The lands subject to overflow are separated under two classifications, those located below the water line of the pool at low water, and consequently always under water, and those above this line, and consequently overflowed only during high water stages, the frequency and duration of such inundations depending upon the height of the lands above pool level.

In estimating the land permanently overflowed in the one case studied it is assumed that all land below the contour 1 foot above the crest of the proposed dam should be included in this classification. This depth over the crest plus the discharge through turbines being sufficient to pass the discharge of the river below those stages normally considered as small floods. In former studies of this character in this district it has been assumed that agricultural land overflowed in this way is permanently withdrawn from agricultural use and the value of the damages allowed in such cases has been based upon this assumption. The case of the Hales Bar Dam in the Tennessee River below Chattanooga is an excellent illustration of this point. Here the power company paid as a damage claim the full market value for all agricultural land below the low water line of the pool and under the assumption that this land was gone forever it omitted to take title to this land. As a matter of fact the Tennessee River carries silt at all stages and at high stages it carries a very large amount. The increased depth caused throughout the length of the pool by the dam gives to the stream at all stages a larger cross-sectional area and consequently a slower velocity than exists outside the pool limits. Hence the deposition of silt goes on at all stages and is very rapid at high stages. Measurements made during the spring of 1921, after this action had been going on for seven years, showed a depth of deposit over the original land surface in flooded areas of almost exactly 7 feet. There is abundant evidence visible to the casual observer to confirm this measurement. For long stretches banks of silt now stand well above the water level at ordinary stages, these in general following the line of the old bank before it was submerged by the pool. Islands which were submerged to a depth of 3 to 12 feet now stand above the water in about their original form. It is evident that many acres of agricultural land which at the outset were completely submerged and for which the power company paid as damages the full market value have not only been built up to a permanent level well above pool stage but are now again in the possession of their original owners, are cultivated as much as ever and their value is equal to, if not greater than, that before they were flooded. This deposit is going on continuously and it is now accepted as a fact by both the power company and the farmers concerned that it is only a question of a few years more until all the former low lying farm lands that were submerged by the pool will be built above ordinary pool level and will be just as valuable farm land as ever.

It is especially to be noted that this result has come wholly from natural causes. No effort has been made to control or direct the action of the silt-bearing water. Funds and time have not been available for experiments but it is believed to be certain that by putting in, in the proper places, light brush fences, low inexpensive stone dikes, by encouraging the growth of willows in some places and clearing them away in others, the deposit of this silt can be made much more rapid and uniform.

Considering this experience in connection with possible power developments on the Upper Tennessee River, similar in all essentials to that at Hales Bar, it seems proper to conclude that overflowed farm land is not damaged to 100 per cent of its value and owners should be willing to accept something less than this as damages. Should the

owners be unwilling to do this, then the agency paying damages should take title to the overflowed lands and in this event it is probable that much if not all the money spent in this way could be recovered in the future through the sale of these lands after they had been built up by silt above pool level.

As to the rate at which it is to be expected that silt will be deposited in the upper river, it might at first be thought that, since the volume of discharge and hence the volume of silt carried is smaller in the upper river than it is in the lower, the rate of deposit will be slower. On the other hand, it will be realized that this fine silt is deposited only as the water carrying it comes to practically complete rest. Having come to rest, the amount of silt deposited depends only upon the amount which was carried in suspension by that much of the water which happens to have left the main channel and slowly come to rest in shallow areas. The volume of water which does this is but a small fraction of that which actually flows down the river, and the amount of silt carried from the channel over shallow areas and deposited should therefore be practically the same from one end of the river to the other. It is believed that future experience will confirm this opinion.

This silting process has been so extensive and obvious in the Hales Bar Pool that it is a matter of common knowledge among that part of the population which is interested in the river not simply in connection with the development of navigation but also in connection with the local flood problem. This knowledge happens to be of some importance in view of the fact that many if not most of these people have drawn the erroneous conclusion that this deposit of silt is raising the bed of the river, hence the surface of the river and consequently the height of flood stages at Chattanooga. For this reason it seems proper to state at this time that it is obvious that the building of the Hales Bar Dam or any other dam in the Tennessee River does not in any degree vary the quantity of water which flows past Chattanooga or any other point during the course of a year. This quantity has, on the average, doubtless remained practically constant for hundreds or thousands of years. The channel through which the river now flows is that developed through the ages by strictly natural causes to be best suited to take care of this average and normal variations therefrom. When a dam is built across the river this raises the water surface and gives to the stream a larger area of cross section than it theretofore has had which was always sufficient to take care of all discharge, small or large. Nature, finding that the river has an unnecessarily large cross-sectional area, begins at once to restore the balance by silting up the excess space, at the same time keeping open all that which is needed for the flow of the stream, and to maintain the necessary rate of flow the former slope at high stages has to be maintained and this can be done only by keeping the channel bed at its original elevation. Fill should and obviously does occur at the sides of the channel over submerged flats and the like, but it does not occur in the channel except possibly in the immediate vicinity of the dam where there is probably some excess depth as well as width. In this connection one interesting feature is less generally appreciated. The Hales Bar Pool now includes several places in the mountain section where the width of the river was greatly restricted by rocky spurs extending out from the hills on each side, giving an effect somewhat similar to a series of hourglasses. Now nature is taking full advantage of the greater depth and width furnished by the pool to keep open a straighter channel of more nearly uniform width, which if it has any appreciable effect on floods tends to diminish their height.

Finally, it is also to be remembered that pools on the Tennessee River can have no value for storage other than that needed for hourly or perhaps daily variation. For this reason this silting process, so objectionable in a storage reservoir, is entirely harmless here when it is realized that in the future as in the past nature will keep open a channel sufficient for the discharge of all water entering the stream. It will be proper, therefore, to do everything possible to encourage the rapid building up by silt of submerged farm lands.

HAROLD C. FISKE,
Major, Corps of Engineers.

APPENDIX F.

THE POWER SITUATION DURING THE WAR.

[Extract from War Department Document 1039 (summary on pp. 235 to 238, inclusive) submitted December 13, 1919, by Col. C. Keller, Corps of Engineers.]

This report states briefly the power requirements of the Southern States and the conditions under which this power is now supplied, and makes recommendations for improving and increasing power generation to provide for public and private needs.

The requirements are now supplied partly by central station electric systems, which serve diversified industries, and partly by isolated steam or water power plants built and operated individually for specific factory or other needs. In the interest of economy, reliability, and conservation isolated plant generation should be discontinued and central power substituted. Industrial development in these States and the conversion of isolated plant service and improvement of power supply will require within the next five to seven years, according to approximate estimates, 1,000,000,000 kilowatt hours increase in annual production, of which 300,000,000 kilowatt hours is allocated to the Carolinas and 700,000,000 kilowatt hours to the States of Tennessee, Alabama, and Georgia.

The investigation made for the purpose of this report does not include a conclusive investigation of the power resources in the Carolinas. With the data at hand we are unable to indicate that the Carolinas have any natural resources in hydro power or other sources that are suitable for the creation of this new power on a basis that would compare favorably with the production by a proposed tri-State interconnected system as described for Alabama, Georgia, and Tennessee, and it appears probable that a large part of the additional power required in the Carolinas could be more economically derived from the interconnected system of these three States. If the anticipated increase for the Carolinas is derived from these three States, the developments recommended for the latter will have a sufficient excess generating capacity to supply the Carolina requirements.

There are certain large hydro developments that have been constructed and others that are projected in Tennessee and North Carolina by private interests for the purpose of manufacturing aluminum. These developments and projects have not been considered in this report as part of the proposed interstate power system for the reason that the resources and requirements of the private aluminum manufacturing interests are not set forth with sufficient assurance regarding future conditions to permit of establishing a measure of the value of their resources in combination with interstate transmission lines. Unquestionably, if an interstate combination is built up as described and recommended in this report, benefit will accrue both to the aluminum manufacturing concern and to the interstate systems if interchange of power is arranged for.

In estimating the additional power service that can advantageously be rendered by the central station systems account has been taken of the established central station business and the reasonable expected increase in going industries. Provision has not been made in these recommendations for extraordinary additions to the power service to provide for a large new electrochemical undertaking or for railroad electrification. One billion kilowatt hours increase, as described, is the foreseen requirements without these new industries of electrochemical and railroad electrification.

The major central station systems at present in operation in the States of Alabama, Georgia, and Tennessee have an aggregate prime generating capacity estimated at 1,230,000,000 kilowatt hours annually, and it is estimated that the central station output should be increased by 700,000,000 kilowatt hours annually to provide for the conversion to central station service of power now being generated by isolated plants and for normal industrial growth anticipated within the next five to seven years.

As the best means of increasing the aggregate capacity of the central power systems of the three States and to improve economy and reliability, it is recommended that the major power systems now in these States be effectively interconnected by transmission lines and the best available resources for hydro and steam power be developed to increase the interstate combined system.

An examination of the central power systems for 1919 conditions shows that these systems, when operated individually, have an aggregate generating capacity capable, under commercial conditions, of producing 1,230,000,000 kilowatt hours of prime power annually, of which 13 per cent, or 163,000,000 kilowatt hours, in seasons of normal river flow would have to be produced by steam plants, requiring a consumption of 190,000 tons of coal annually. By effectively interconnecting these systems and operating them for the best joint economy the capacity of the combined systems would be increased to 1,370,000,000 kilowatt hours annually, requiring, in years of normal river flow, the production of 132,000,000 kilowatt hours by steam, with a consumption of 140,000 tons of coal. An increase of 140,000,000 kilowatt hours in the generating capacity is effected by complete interconnection and joint operation, as above, which in itself is an important reason for interconnection.

In building for increased power production needed to convert isolated plant service to central station operation and to provide for industrial growth, the proposed interstate interconnected power system affords a marked advantage over the present plan of independent disconnected or inadequately interconnected systems, particularly as the interconnected systems would permit the use of the most economical

sources of power within the area of the proposed interstate system, regardless of the relative location of these sources to localized market centers.

Contemplating the adoption of this plan, and in order to provide increased power facilities for the production of 700,000,000 kilowatt hours annually (the estimated requirements for isolated plant conversion and industrial growth within the next five to seven years), it is recommended that the hydroelectric plants be built on the Tallapoosa River, Ala., near Cherokee Bluff, together with a large storage reservoir. The present power systems combined with the proposed Tallapoosa plants would have a generating capacity of 2,100,000,000 kilowatt hours annually, which is an increase of 730,000,000 kilowatt hours over the capacity of the present systems if interconnected and jointly operated.

Building for increased power production in the three States under consideration should not, and will not, cease with the installation of 700,000,000 kilowatt-hours increase in annual capacity. It is anticipated that with this increase provided for during the next five to seven years, still further increased capacity should be undertaken for growth following the five-year period, and the recommendation of Tallapoosa is made with a view to later additions to the generating capacity of an interstate power system for Alabama, Georgia, and Tennessee, and possibly the Carolinas. Developments which compare favorably with the Tallapoosa project have been examined and considered:

(a) On the Chattahoochee River, at Bartlett's Ferry, in western Georgia, for increasing the capacity of the interstate system by 170,000,000 kilowatt-hours annually.

(b) Two developments, referred to as Tugaloo and Mathis, on the Tugaloo River, in northeastern Georgia, for increasing the capacity of the system by 240,000,000 kilowatt-hours annually.

A large number of other developments, including steam plants at coal-mine centers, were examined and compared but considered less favorable than those mentioned above as components of the power system composed of the present central-station systems adequately interconnected.

The great advantages of interconnection and joint operation of power systems, and the economies in building for increase in generating capacity, as herein stated, apply equally to a combination of the privately owned power companies with the Government powers now building at Muscle Shoals. The characteristics of this Government power and the gain, both to the Government power and to the privately owned powers, that would result from interconnection and exchange of facilities, was an important consideration in the recommendation of the Tallapoosa River project, inasmuch as the interstate combination, with other power substituted for Tallapoosa, might be quite as favorable as the Tallapoosa powers in a combination without Muscle Shoals.

Under the present laws, the Government Muscle Shoals hydropower now building can be connected to or operated in conjunction with private interests.

The Government hydro power at Muscle Shoals will be on a variable river with opportunity for the development of a vast amount of second-class, or 9 months' power, and a relatively small proportion of 12 months' or primary power. A Government-owned steam plant being built at Muscle Shoals will be capable of converting a portion of the second-class power into prime power, but it can not do so as economically as the combination with the proposed interstate power system, because if steam plant auxiliary power is to be used with the Muscle Shoals power, other steam plants already constructed are more favorably situated than the Government steam plant for furnishing the bulk of this supplementary steam power.

Still further, if the Government needs do not require the entire output of the Muscle Shoals plants, it would be a criminal waste to deprive the industries of Alabama and adjacent States of this supply of power. We want to emphasize that an interconnected power system, as herein recommended, is the best possible vehicle for taking over such part of Muscle Shoals power as the Government may not require for its own uses, and delivering it to the Southern States industries, and that to make provision for doing this efficiently, such use of the surplus power should be arranged for at a very early date, and considered in connection with private plant developments to the end that these developments may be of a character that will advantageously supplement Muscle Shoals.

It is recognized that the resources for cheap power in the Southern States are one of their most valuable assets industrially, and Muscle Shoals hydro power has long been looked upon as a favorable project, particularly in combination with Tennessee River improvements for navigation, and prior to the war a private corporation even went so far as to spend some hundreds of thousands of dollars in securing property rights and exploring foundations and making designs. It appears that with an exchange of power between the Government interests and private power systems, maximum economy will result to both interests, whereas, if the present law is enforced,

the Government will lose the economic advantage of interchanging power with existing privately owned systems and the southern industries will be deprived of the benefit of Muscle Shoals power.

The proposed interstate power system above described, including the proposed Tallapoosa River developments, and capable, as stated, of producing 2,100,000,000 kilowatt-hours of prime power annually, if combined and operated in conjunction with a hydro plant at Muscle Shoals with 300,000 kilowatts ultimate installed capacity as proposed, would be capable of producing, in years of normal river flow, 2,880,000,000 kilowatt-hours annually of prime hydro power without any steam generation.

APPENDIX G.

COST ESTIMATES.

In the following estimates the figures published in the report on the superpower system for the region between Boston and Washington, in so far as they pertain to costs of generating and transmission equipment, have been used freely as a guide. In doing so it was realized that the figures there given, being applicable to conditions as of 1919, are higher than market prices at time of submitting this report. Nevertheless, it was felt that since immediate construction is not contemplated, and prices will probably regain higher levels after the present period of depression is past, the figures adopted will be in excess of probable construction costs by no more than a reasonable margin.

The estimates are based on the following considerations:

Foundations.—The river at the dam site flows in part over solid rock, and in part over a bed of boulders, where a navigable channel was excavated some years ago. Solid rock is visible at low water across the entire west channel and consists of hard chert layers, which form part of dolomite beds of great thickness. Pending exploration by means of core drills, it is assumed that a proper footing for a dam can be secured by the removal of a comparatively small amount of decayed surface rock and the blasting out of necessary toe and heel trenches.

Abutments.—Outcrops along both banks are numerous and indicate substantial dolomite formations extending up to the full height of the dam, which will require only a limited amount of excavation.

Type of dam.—A straight dam of gravity profile with ogee crest appears best adapted to this site. Top of dam to be at elevation 799, or about 53 feet above present low-water surface. The maximum height of masonry is estimated at 67 feet. The overall length, including power house substructure, but not including the locks, will be 1,400 feet, of which 1,200 feet will be unobstructed spillway.

Materials at site.—Old quarries at the dam site show rock to be hard dolomite interspersed with layers of chert, which is suitable for coarse concrete aggregate. No adequate supply of sand has been located at the site, but is doubtless available along the river within reasonable hauling distance by water.

Transportation.—Transportation facilities at present consist of the main line of Louisville & Nashville Railroad between Knoxville and Atlanta, which passes within 5 miles of the dam site, with nearest station at Friendsville, Tenn., situated 21 miles from Knoxville. There would be a truck haul of 6 miles from Friendsville to the site, 1 mile of which is over macadamized roads and 5 over fair dirt roads which will have to be improved if given heavy traffic.

Concrete.—The cost of concrete in dam and power-house substructure has been placed at \$12, which makes allowance for cost of cofferdamming, stream control, and excavating of foundations. This was done because of inability to make intelligent separate estimates of the latter quantities. In the case of the locks separate estimates of excavation and cofferdamming could be made, and the cost of concrete for these structures is accordingly lower by \$2 per cubic yard.

Power-house substructure.—It was estimated that the substructure would have approximately the same cost per linear foot as an equivalent length of dam.

Locks.—The estimate provides for a flight of two locks aggregating 60 feet in lift, chambers to be 60 feet wide and 300 feet long in the clear.

Power house and equipment.—Costs are based on an assumed installation of four 8,200-kilowatt units, and 3-phase 60-cycle equipment. Turbines, generators, switch gear, and wiring are estimated together at \$34 per horsepower of installed capacity, and with power-house structure and accessories included at \$45 per horsepower.

Transmission lines.—The power site being midway between two high-tension transmission lines running into Knoxville, it did not seem reasonable to assume the construction of a third line from Coulter Shoals to Knoxville. The estimate covers,

therefore, the two 5-mile connections required to connect the power plant with the existing lines. Steel-tower, double-circuit lines have been assumed, suitable for transmission at 110,000 volts. The cost was figured at \$4,000 per mile, inclusive of right of way.

Substations.—The usual equipment has been allowed for, but no synchronous condensers are included, the power plant being so near to Knoxville, its principal distributing center, as to render condensers unnecessary.

Land damages.—Of the 3,800 acres of land that will be permanently overflowed, not to exceed 1,000 acres are first-class cultivated lands, the balance consisting of hillside and pasture lands, gullied lands, and wooded areas. The market values of lands are estimated as follows: First-class bottom land, \$100 per acre; good hillside cultivated or pasture land, \$50 per acre; gullied lands and timber tracts, \$25 per acre. It has been assumed that the purchase price would be double the above values.

Damage to other property.—No industrial plants nor any buildings of importance stand within the area to be inundated. A number of small town lots, farm houses, and dwellings will be rendered subject to overflow by increased flood levels. About 10 miles of surfaced public highways will have to be built to replace portions that will be inundated, including a small two-span concrete bridge over Little River. No railroads are below the level of the pool, but it may become necessary to elevate the grade of the Southern Railway for about 4 miles near Concord, Tenn., to raise the track above increased maximum flood level. No interference with sand dredging operations about Knoxville will result, the increased depth there not being sufficient to affect such operations. Present knowledge of the various damage features here enumerated is insufficient to make any more than a liberal lump-sum estimate at this time.

Construction cost.

Dam and power-house substructure, 117,000 cubic yards of concrete, at \$12.	\$1, 404, 000
Power-house and mechanical equipment, wiring, etc., capacity 44,000 horsepower, at \$45 per horsepower.	1, 980, 000
Transmission lines, 10 miles of steel tower lines, including right of way, at \$4,000.	40, 000
Substations for two 110,000-volt circuits, including transformers, structures, and switch gears; capacity, 33,000 kilowatts, at \$8.	264, 000
Locks, two flights totaling 60-foot lift:	
Cofferdam, 300 linear feet, at \$30.	\$9, 000
Earth excavation, 250,000 cubic yards, at 50 cents.	125, 000
Rock excavation, 42,000 cubic yards, at \$3.	126, 000
Back fill and embankment, 25,000 cubic yards, at 25 cents.	6, 250
Concrete in lock, guide and guard walls, and paving, 50,000 cubic yards, at \$10.	500, 000
Bolt and test holes, 3,000 linear feet, at \$1.50.	4, 500
Handling and placing steel, 300 tons, at \$50.	15, 000
Steel lock gates and operating machinery, 1,000 tons, at \$165.	165, 000
Valves and machinery, lump sum.	80, 150
Houses and grounds, lump sum.	50, 000
	1, 030, 900
Lands for buildings, flowage lands, damages to railroads, highways, etc., assumed lump sum.	700, 000
Engineering and contingencies, 16 per cent.	877, 800
Total.	6, 346, 500

In the event that the dam, lock, and power plant should be built by a private corporation there should be added to the above an item allowing for interest during construction, and to the cost of locks should be added \$100,000 to cover the cost of Government inspection during construction. The latter item presumably would be borne by the Government.

Annual power production cost.

Depreciation:	
Dam and power-house substructure, at 1 per cent.	\$14, 040
Power house and equipment, at 3 per cent.	59, 400
Transmission lines, at 2 per cent.	800
Substations, at 4 per cent.	10, 560
	\$84, 800

Operating expense:¹

Attendance, oil, waste, supplies, at 0.9 per cent.....	\$47,300
Maintenance (labor and materials), at 1 per cent.....	52,600
Overhead, including engineering and legal, at 1 per cent.....	52,600
Operation of locks.....	20,000
	<hr/> \$172,500

Total annual power production cost..... 257,300

Unit cost of power produced.

Average year:	Kilowatt hours.
Primary power, 91,500,000 kilowatt hours, at 70 per cent load factor..	64,050,000
Secondary power, 145,500,000 kilowatt hours, at 50 per cent load factor.....	72,750,000
Total sold.....	136,800,000
Cost per kilowatt hour, 1.9 mills.	
Extreme low-water year:	
Primary power, 90,600,000 kilowatt hours, at 70 per cent load factor..	63,420,000
Secondary power, 96,500,000 kilowatt hours, at 50 per cent load factor.....	48,250,000
Total sold.....	111,670,000
Cost per kilowatt hour, 2.3 mills.	
High water year:	
Primary power, 91,500,000 kilowatt hours, at 70 per cent load factor..	64,050,000
Secondary power, 166,500,000 kilowatt hours, at 50 per cent load factor.....	83,250,000
Total sold.....	147,300,000
Cost per kilowatt hour, 1.75 mills.	

The construction cost of the project, eliminating the locks, is \$5,265,600, or at the rate of \$120 per horsepower, or \$160 per kilowatt of installed capacity. Adding interest during construction, say, half a million dollars, the cost per kilowatt is \$175, which is a reasonable figure for the investment cost of a hydroelectric development.

The foregoing cost analyses are on the basis commonly adopted for making estimates for public works to be built by the United States. This has been done purposely in order to eliminate all items properly chargeable to corporation financing. Thus, under the head of construction cost no cognizance has been taken of interest charges during construction period, nor are fixed charges other than depreciation included under the head of production costs.

It is a well-known fact that in the operation of public-utility hydroelectric plants fixed charges constitute by far the largest single item in power-production costs, averaging in the neighborhood of 80 per cent of such costs. In 1920, when money rates were soaring, fixed charges mounted as high as 87 per cent of production cost and 14 per cent of investment cost. Depending upon the plan adopted for financing such an undertaking as this, the amounts payable annually in the form of bond interest and dividends to stockholders are likely to vary materially. Yet these form, in effect, the major portion of the fixed charges.

Different methods, also, are pursued in the handling of interest during construction, depending largely upon the plan adopted for selling the securities and upon the length of time involved in making deferred payments in acquiring title to lands and the settlement of damage claims.

During the past two years the cost of money has declined, in the case of bond issues for public-utility plants, from 8 per cent to 6 per cent, and since January, 1922, has dropped to 5 per cent and even lower offerings, with no certainty as to the direction which future changes will take. It has, therefore, seemed desirable to defer definite determination of all cost items bearing on corporation financing until such time as a concrete case presents itself, when, for obvious reasons, their determination will have to be governed largely by the desires of the parties in interest.

COSTS OF HYDROELECTRIC AND STEAM-ELECTRIC POWER COMPARED.

Because of the extensive use that is being made of steam machinery about Knoxville for generating power, and the more or less prevailing local impression that because

¹ Percentages refer to total cost of construction exclusive of locks.

of proximity to coal mines electric energy can be generated there more cheaply than from water power, the following comparison between costs of steam-electric and hydro-electric power seems pertinent:

Table No. 4 shows the fuel cost per kilowatt hour of power generated by the largest modern steam installations east of Indiana and north of Virginia for prices of coal prevailing in 1915 and in 1918.¹

It will be seen that this cost ranged before the war from as low as 2.03 mills per kilowatt hour for coal costing \$1.71 per short ton delivered at the plant and an average consumption of 2.36 pounds per kilowatt hour to as high as 4.45 mills for coal costing \$3.56 per ton and a consumption of 2.50 pounds per kilowatt hour. With the increased cost of prices resulting from the war, the cost per kilowatt hour was practically doubled. The grand averages for all these plants before and after the war were 3.19 and 6.49 mills per kilowatt hour, respectively. It may be concluded from this that the fuel cost of generating electric power by steam plants of modern design, with coal delivered at \$3 per ton, which is a fair price for the Knoxville district, and assuming a consumption of 2.5 pounds of coal per kilowatt hour, would in no case fall below 4 mills per kilowatt hour.

TABLE 4.—*Fuel cost of steam-generated electric power.*

Location.	Kilowatt hours generated in 1918.	Coal.	Coal per kilowatt hour.	Cost per short ton.		Total fuel cost.		Cost in mills per kilowatt hour.	
				Pre-war.	1918	Pre-war.	1918	Pre-war.	1918
New England (6 States, 97.8 per cent of total steam generated).	1,283,000,000	<i>Short tons.</i> 1,606,000	<i>Pounds.</i> 2.50	\$3.56	\$7.31	\$5,718,805	\$11,745,963	4.45	9.15
New York City (New York Edison and United Cos. Only close estimates).....	958,878,000	1,060,000	2.2	2.90	5.80	3,074,000	6,148,000	3.21	6.41
New Jersey (Philadelphia and Wilmington public utilities plants)...	1,515,944,000	1,946,397	2.57	2.74	5.02	5,339,158	9,761,553	3.52	6.45
Baltimore.....	210,914,000	265,912	2.52	2.41	4.84	640,847	1,289,008	3.04	6.11
Buffalo, Lyons (Rochester and Geneva public utilities plants)...	432,070,000	499,337	2.31	2.44	4.82	1,218,513	2,405,016	2.82	5.57
Cleveland (Toledo and Lorain public utilities plants)	694,868,000	821,993	2.36	1.71	3.87	1,409,315	3,172,839	2.03	4.57
Pittsburgh (eastern Ohio public utilities plants; Windsor plant omitted)	1,509,316,000	2,422,255	3.2	1.51	3.41	3,655,895	8,266,057	2.42	5.48
Total.....	6,604,990,000	8,621,894	2.61	2.44	4.96	21,056,533	42,788,436	3.19	6.49

¹ Compiled from "Report on power situation during the war," by Col. Charles Keller, p. 104.

TABLE 5.—*Operating and maintenance costs of six steam plants of modern design in Massachusetts per kilowatt hour of energy generated, for year ending June 30, 1921.*

Company.	Rated plant capacity in kilowatt hours.	Energy generated in kilowatt hours.	Plant operating cost exclusive of fuel cost.		Plant maintenance cost in mills per kilowatt hour.				Total plant operating and maintenance cost per kilowatt hour.
			Total.	Per kilowatt hour.	Building.	Steam equipment.	Electric equipment.	Total.	
				<i>Mills.</i>					
A.....	23, 150	34, 232, 840	\$115, 753	3.38	0.13	0.68	0.28	1.09	\$4.47
B.....	25, 787	29, 194, 096	1'4, 857	5.31	.29	.86	.23	1.38	6.19
C.....	18, 437	29, 056, 200	99, 326	3.42	.09	.79	.08	.96	4.38
D.....	20, 265	30, 144, 388	128, 536	4.26	.13	1.22	.18	1.53	5.79
E.....	77, 500	81, 691, 800	218, 871	2.68	.29	.64	.10	1.03	3.71
F.....	59, 700	63, 140, 000	269, 899	4.28	.37	1.60	.22	2.18	6.46
Averages.....				3.89	.22	.96	.18	1.36	5.25

Turning next to operating and maintenance costs, Table No. 5¹ gives figures for six efficiently managed Massachusetts plants equipped with water-tube boilers, mechanical stokers, turbogenerators, and condensers, for the year ending June 30, 1921.

Fuel costs have been eliminated from this tabulation in order to make it comparable with similar costs for hydroelectric plants. Operating expense is seen to vary from 2.68 to 5.31 mills per kilowatt hour, with an average for all the plants of 3.89 mills. Maintenance expense amounts to from less than 1 mill to over 2 mills per kilowatt hour, with an average of 1.36 mills. The distribution of this latter item to its three principal components, viz, buildings, steam equipment, and electrical equipment, has been inserted purposely to demonstrate that the cost of upkeep of steam machinery in such plants is by far the largest item of plant maintenance, averaging five times as much as the upkeep cost of the electrical equipment. It alone amounts to nearly 1 mill per kilowatt-hour.

Operating and maintenance costs, including fuel cost, should average, therefore, together about 8 mills. When to this is added overhead expense and fixed charges, the total cost of steam-generated power is seen to be well in excess of 1 cent per kilowatt-hour under the most favorable of conditions, and in ordinary plants exceeds 2 cents.

The following table compiled from data published in the report of the superpower system for the region between Boston and Washington gives a direct comparison between the annual production costs for the steam and hydroelectric plants in the region investigated. This tabulation is not limited to selected high-class modern plants, but includes plants of all types and sizes, and brings out in still greater contrast the superiority of water power over steam power.

TABLE 6.—*Total annual production cost of steam-electric and hydroelectric utility plants in the superpower zone, 1919.*

Geographic division.	Cost per kilowatt hour in mills.	
	Steam-electric.	Hydro-electric.
Eastern New England.....	26.4	10.2
Western New England.....	29.7	10.9
Mohawk.....	67.0	10.9
Metropolitan.....	18.2	19.4
Hudson.....	37.5	14.7
Anthracite.....	18.6	16.1
Southern.....	20.2	6.6
Weighted averages.....	21.24	9.4

¹ Compiled from *Electrical World*, Jan. 21, 1922, pp. 131-132, and from data furnished by Massachusetts Department of Public Utilities.

The annual production cost of all the power plants in the superpower zone for 1919 is given for fixed charges, operating expense, and general expense in percentages of total cost, as follows:

	Steam electric.	Hydro-electric.
	<i>Per cent.</i>	<i>Per cent.</i>
Fixed charges.....	44.5	81.0
Operating expense.....	49.7	11.1
General expense.....	5.8	7.9

GERARD H. MATTHES,
Assistant Engineer.

APPENDIX H.

REPORT OF THE STATE GEOLOGIST.

STATE OF TENNESSEE,
STATE GEOLOGICAL SURVEY,
Nashville, January 14, 1922.

Maj. HAROLD C. FISKE,
Chattanooga, Tenn.

DEAR MAJOR FISKE: Attached to this letter you will find a photograph of Coulter Shoals on which I have placed strike and dip symbols on ledges of dolomite which crop out at this point.

The bed of the river in the area examined from the upper to the lower end of Coulter Island is a heavy bedded dolomite containing chert layers at irregular intervals. Some of these chert layers appear to be 1 or 2 feet thick. The dolomite itself is more or less siliceous and would not be as subject to solution as limestone. From the examination made of Coulter Shoals I would consider that from a geological standpoint the best foundation for a dam would be found just below the middle of Coulter Island where I show the symbol on the west side of the river showing 10 degrees dip and where I show the symbol on the east side of the river showing 12 degrees dip. At this point the dolomite layers are more massive and appear to contain more chert and silica than near the upper end of the island or the lower end of the island.

From a geological standpoint, a dam foundation at this point offers no insurmountable difficulties to engineers although it would be absolutely necessary to do extensive core drilling at this point to determine to what depth surface solution has taken place. The conditions are in no respect similar to those at Hales Bar and it is considered that a water-tight foundation can be obtained if the engineering work in connection with the core drilling is carried on in detail and under expert supervision.

There is no fault in the rocks at this point, and as shown on the map these rocks have a practically uniform dip, flattening out slightly as you go south along the river. A maximum dip of 21° was seen north of the north end of Coulter Island and a minimum dip of 7° was seen at the western bank of the river opposite the southern end of this island.

Yours very truly,

WILBUR A. NELSON, *State Geologist.*

APPENDIX J.

POWER AVAILABLE AT COULTER SHOALS.

Water supply.—The available flow at the Coulter Shoals site has been computed from the stream flow record for Knoxville, Tenn., where a gauge has been maintained since 1883. The early years of this record are fragmentary and of little value for making estimates of power. However, since 1899 the gauge has been read regularly by the Weather Bureau and the record is dependable. A number of measurements of the flow of the river have been made in the past by both the United States Geological Survey and the Engineer Department, and the relation between stage and discharge has been fairly well established. Since October, 1920, when a cooperative stream

gaging program for the Tennessee Basin was initiated by this office in conjunction with the Water Resources Branch of the United States Geological Survey, 11 discharge measurements have been made at Knoxville. As a result a well-defined rating curve is now available up to a stage of about 20 feet. The highest measurement available was made on March 24, 1903, showing a discharge of 126,400 cubic feet per second for a stage of 22.6 feet. Since floods as high as 30 and 40 feet have been recorded at Knoxville, it becomes necessary to estimate such flood discharges by extending the rating curve. Owing to various changes that have occurred, not only in location of the gauge but also in the elevation of its zero point, it was found necessary to examine the record of daily discharges quite critically and to discard any portions that seemed unreliable. By this process a gap of 12 months was caused from October 1, 1917, to September 30, 1918, during which time the relation between stage and discharge changed gradually, due to channel improvements that were being made in the vicinity of the gauge by the War Department. With the exception of these 12 months, the record from October 1, 1899, to December 31, 1921, was considered safe to use for the purposes of this study, and 21 years of river flow are thus available for consideration. This record, and also the rainfall statistics for the same period, show that these years are quite representative of river conditions at Knoxville. They include 1904, a year of unusually low water flow, when the total discharge was little more than half that of an average year, and 1901, a year of high water, during which floods exceeding 75,000 cubic feet per second occurred, one each in January, March, May, and August, and two each in April and December. The total annual discharge amounted to one and one-half times that of an average year.

The drainage area of the Tennessee River above the Knoxville gauge is 8,990 square miles. At Coulter Shoals, 40 miles farther downstream, the area is 9,574 square miles. In this distance, the only tributary of any note emptying into the Tennessee is Little River, which has a drainage area of 376 square miles.

To compute the flow past Coulter Shoals it has been assumed that the increase in flow between Knoxville and the Shoals would be proportional to the respective areas drained. Comparison with the record of flow at Chattanooga shows that this method of computing discharge may be used without material error for determining the low water flow of the Tennessee River. At time of high water the great variation that occurs in the amounts contributed by individual large tributaries renders the method not so reliable. However, since the low water stages are the prime consideration in this study and the higher stages only of minor interest, the method seems well adapted for the purposes in hand. Besides, Little River is hardly to be classed among the large tributaries, its flood flow being small in comparison with that of the parent stream.

The lowest flow at Knoxville, during the period considered, occurred September 16, 1911, when the discharge according to the United States Geological Survey rating table was 1,460 cubic feet per second. This occurred on only one day, the flow for the two days previous being 1,790 and for the two days following 2,160 and 3,010 cubic feet per second, while the average for that entire month was 4,450 cubic feet per second. The minimum of 1,460 cubic feet per second is not duplicated elsewhere in the record, and leads one to suspect it to be caused by an error in the reading of the gauge. The next low figures are 1,620 on October 5, 6, and 7, 1903, and 1,790 on October 25, 26, and 27, 1904. Outside of these extreme low stages none of the remaining 18 years showed a 24-hour discharge below 1,970 cubic feet per second. The average of the 21 yearly minimum at Knoxville was 3,013 cubic feet per second. Table No. 7 gives for Coulter Shoals the minimum flow for each year and the dates of occurrence, also the lowest month of each year and its mean rate of flow in cubic feet per second. The lowest stages are seen to occur usually in September, October, or November, and rarely last more than 3 or 4 consecutive days. The minimum 24-hour flow on September 16, 1911, amounted to 1,555 cubic feet per second, and the minimum rates of flow of all the years averaged 3,210 cubic feet per second. The lowest month in the record, viz, October, 1904, had a mean discharge of 2,140 cubic feet per second, and the average of all the low months for the entire period was 5,188 cubic feet per second.

TABLE 7.—*Low water flow at Coulter Shoals for period 1900–1921.*

Year.	Minimum flow.		Mean flow for lowest month.	
	Cubic feet per second.	Dates.	Cubic feet per second.	Month.
1900.....	2,740	Sept. 13, Oct. 23.....	5,600	September.
1901.....	4,830	Nov. 21–22.....	5,590	November.
1902.....	3,450	Oct. 24–28.....	5,270	October.
1903.....	1,725	Oct. 4–7.....	2,840	Do.
1904.....	1,907	Oct. 25–27.....	2,140	Do.
1905.....	3,450	Nov. 18–19, 27–29.....	3,680	November.
1906.....	6,950	July 14.....	13,200	June.
1907.....	4,540	Oct. 24–28.....	6,480	October.
1908.....	3,450	Sept. 19–28, Oct. 9.....	5,870	September.
1909.....	2,970	Dec. 6.....	4,250	November.
1910.....	2,100	Nov. 22–24.....	3,490	Do.
1911.....	1,555	Sept. 16.....	3,960	August.
1912.....	2,515	Dec. 2, 3, 17.....	4,890	October.
1913.....	2,740	Sept. 15.....	4,950	Do.
1914.....	2,300	Oct. 1, 2, 13, 14.....	3,580	September.
1915.....	3,710	Sept. 30.....	7,900	August.
1916.....	3,210	Oct. 16–17.....	4,830	November.
1917.....	2,300	Sept. 22.....	6,180	September.
1918.....	3,220	Sept. 19–22, 28; Oct. 3, 4.....	4,000	Do.
1920.....	4,430	Oct. 20–21.....	5,730	October.
1921.....	3,310	Oct. 23, 27, 31.....	4,470	Do.
Minimum.....	1,555	September, 1911.....	2,140	October, 1904.
Average.....	3,210	.....	5,188	.....

It should be stated in this connection that the average rate of flow for the entire 21 years under consideration was 13,700 cubic feet per second, as against an assumed installed water-wheel capacity of only 10,000 cubic feet per second, showing the latter figure to be quite conservative.

Plate XIII shows graphically the percentage of time that various rates of flow would have been available at Coulter Shoals (a) in a year like 1901, which was noted for its sequence of floods; (b) in a year like 1919, which is as nearly a typical average year as could be found in the record; (c) in a year like 1904, which, so far as is known, has not been equaled or exceeded as regards protracted low-water flow. It shows, furthermore, that a flow of 3,000 cubic feet per second (corresponding to primary power used in these estimates) would have been available 100 per cent of the time in years like 1919 and 1901, but only 82.5 per cent of the time in a year like 1904. A flow of 10,000 cubic feet per second (the assumed water-wheel capacity) would have been available 72 per cent of the time in a year like 1901, 57 per cent of the time in a year like 1919, and 28 per cent of the time in a year like 1904. The flow available 90 per cent of the time in an extreme low year like 1904 would have been 2,500, and in the average year 4,000 cubic feet per second.

As regards the probable frequency of recurrence of an extreme low water year like 1904, it should be stated that 1871 and 1884 are said to have been very low years and perhaps as low in minimum discharge as 1904. No definite information is at hand, however, as to the duration of their extreme low stages. By reference to the Knoxville rainfall figures, the fall of 1884 appears to have had more rain than that of 1904, while the rainfall in 1871 was normal, from which it might be inferred that such extreme low stages as did occur in 1871 and 1884 probably were of short duration. On the other hand, 1894 had a very dry fall, and it is presumed that the river must have been quite low that year. These considerations and a study of river stages at Knoxville and Chattanooga lead to the conclusion that long protracted extreme low water stages, such as occurred in 1904, are not likely to occur, on an average, oftener than once in 15 years and probably longer.

Head.—Operating head, in these estimates, has been computed disregarding the use that will probably be made of flashboards, and is taken to be the difference between pool and tail-water elevations. It varies from a maximum of 53 feet in an extreme low-water flow of 1,700 cubic feet per second to as low as 27 feet in the unusual event of a flood discharge of 240,000 cubic feet per second. When the flow is 10,000 cubic

feet per second, which is the assumed joint capacity of the turbines, the corresponding head is 48 feet.

Plate XII shows graphically the elevations of pool and tailwater and the resulting operating heads for any river discharge up to 220,000 cubic feet per second. It illustrates that as the discharge increases the tailwater rises more rapidly than does the pool above the dam, causing a progressively diminishing head, except between 10,000 and 11,000 cubic feet per second, where there is a slight increase in head.

In the upper portion of Plate XIII the head curves show the percentage of time that given heads would obtain in the case of an extreme low-water year, also in an average year, and in a high-water year. For ordinary operating conditions, such as would obtain 90 per cent of the time, the fluctuations in head are shown to cover a range of 5 feet in both the extreme low-water year and average year, and of 6 feet in the high-water year. In the latter case the head, over 90 per cent of the time, would not have fallen below 44 feet. These fluctuations are quite small for a plant of the type under discussion, and should make it possible to maintain high turbine efficiencies. All of the above figures are based on the assumption that the permanent crest of the dam will be at elevation 799. Should a movable crest be found desirable for keeping the pool level down to a given elevation, this can be done only at the expense of loss of head and power at times of high water. This matter and also the conditions that will exist when a second dam is built on the Tennessee River below Coulter Shoals are discussed under the head of "Power output."

Power output.—The proposed plant is on a navigable stream affording no facility at the site for the storage of water sufficient for seasonal regulation. The power available, therefore, is of the "run-of-river" type; that is, the amount generated must, within narrow limits, vary from day to day as the river discharge varies.

An installation of about 44,000 horsepower, or about three times the primary power now available, has been tentatively selected, calling for a turbine capacity of approximately 10,000 cubic feet per second. In after years, as the seasonal variations in river flow become less extreme as the result of regulating works on the upper tributaries, an even greater capacity will doubtless become advantageous, and space should therefore be provided in the design of the power house for the installation of additional generating equipment. Table No. 8 shows, for various rates of river discharge, the 24-hour horsepower that could be produced by a power station at Coulter Shoals with an installed capacity of 44,000 horsepower.

The pool above the dam will have a superficial area of about 6,000 acres, and with 3-foot flashboards would provide a pondage of about 20,000 acre-feet, or sufficient to maintain a minimum flow, in the low-water season, of 3,000 cubic feet per second, corresponding to a power output of 14,000 horsepower at the switchboard at 80 per cent efficiency. In 1904 probably not to exceed 2,500 cubic feet per second can be obtained by means of this method of regulation. However, as has been stated under the head of "Water supply," such a condition is not likely to be met with oftener than once in 15 years, and it would be contrary to good engineering to predicate the amount of primary power on what could be obtained in such an extreme low-water year. Besides, as the power development of the tributaries progresses such extreme minima will cease to occur.

TABLE 8.—24-hour horsepower at 80 per cent efficiency available at Coulter Shoals site with permanent crest of dam at elevation 799 above mean sea level.

River discharge in cu. ft. per second.	Discharge over dam in cu. ft. per second.	Elevation of headwater above mean sea level.	Elevation of tail-water above mean sea level.	Operating head in feet.	Theoretical 24-hour horsepower at 80 per cent efficiency.	24-hour 80 per cent efficiency horsepower with 10,000 cubic feet per second turbine capacity.
1,700	0	799.0	746.0	53.0	8,190	8,190
1,900	0	799.0	746.5	52.5	9,070	9,070
2,000	0	799.0	746.8	52.2	9,490	9,490
2,500	0	799.0	747.5	51.5	11,700	11,700
3,000	0	799.0	747.8	51.2	14,000	14,000
4,000	0	799.0	748.4	50.6	18,400	18,400
5,000	0	799.0	749.0	50.0	22,700	22,700
6,000	0	799.0	749.5	49.5	27,000	27,000
7,000	0	799.0	750.0	49.0	31,200	31,200
8,000	0	799.0	750.4	48.6	35,400	35,400
9,000	0	799.0	750.7	48.3	39,600	39,600
10,000	0	799.0	751.0	48.0	43,600	43,600
11,000	1,000	799.4	751.3	48.1	48,100	43,730
12,000	2,000	799.7	751.6	48.1	52,500	43,800
15,000	5,000	800.2	752.5	47.7	65,000	43,000
20,000	10,000	800.9	754.0	46.9	85,400	42,600
25,000	15,000	801.4	755.0	46.4	105,400	42,200
30,000	20,000	801.8	756.0	45.8	125,000	41,600
40,000	30,000	802.6	757.5	45.1	164,000	41,000
50,000	40,000	803.3	759.1	44.2	200,100	40,200
60,000	50,000	804.1	760.5	43.6	248,000	39,600

NOTES.—Headwater elevations are figured assuming discharge through turbines up to 10,000 cubic feet per second, a length of fixed crest of dam of 1,200 feet, and no flashboards. Tail-water elevations assume river below dam not to be canalized.

Plate XIV shows, by means of a duration curve, the power available in an extreme low-water year, like 1904; similarly, by means of separate curves, the power available in an average year like 1919 and in a high-water year like 1901. The power is expressed in kilowatts at the switchboard, and has been derived from the duration of flow and operating head curves shown in Plate XIII. An over-all efficiency of 80 per cent has been assumed, representing the combined efficiencies of turbines, generators, and auxiliary equipment. This efficiency has been applied to all computations of power presented in this report, on the assumption that it will be possible to select turbines of high specific speed type, having fairly flat efficiency curves, and which will operate at high efficiencies for all heads except those occurring during very high water stages.

The primary power has been placed at 14,000 horsepower or 10,450 kilowatts. This is equivalent to 91,500,000 kilowatt-hours in a year, and at 70 per cent load factor represents an output of 64,050,000 kilowatt-hours of primary power. In an extreme low-water year, like 1904, the primary power on the same basis would probably not exceed 90,600,000 kilowatt-hours or at 70 per cent load factor, 63,400,000 kilowatt-hours output.

The secondary power output has been computed by integrating the areas under the curves on plate XIV, deducting therefrom the primary power, and applying a 50 per cent load factor. In an extreme low year the output would be 48,250,000 kilowatt-hours; in an average year 72,500,000 kilowatt-hours; and in a high-water year, 129,000,000 kilowatt-hours.

All of the above power figures are on the basis of a dam with permanent crest at elevation 799, and having a limited pondage created by means of flashboards. It is assumed, furthermore, an open river below the dam requiring for the maintenance of its present navigable condition a discharge through the powerhouse or dam of not less than a prescribed minimum flow at all times. In the event that a movable crest were provided to maintain a constant pool level at times of high water, the secondary power would thereby suffer reduction at such times. No detailed study of the exact amount of such reduction has as yet been made, but it may readily be seen by reference to Plates XII, XIII, and XIV that if, for instance, pool level were to be kept down to elevation 803, which is one foot higher than top of 3-foot flashboards, this would affect the power production only during river stages in excess of 46,000 cubic feet per

second, and these do not occur oftener than 2 per cent of the time in ordinary years and about 11 per cent of the time in an exceptional high-water year, like 1901. Similarly, if maximum pool level were required not to exceed elevation 805, any reduction in power output thereby caused would occur only during high flood stages aggregating not to exceed 1 per cent of the time in an ordinary year, and not exceeding 2 per cent in a year like 1901. It may be gathered from this that it is quite probable that a limitation of pool level may be worked out which will not materially curtail the power produced. In any event only secondary power will be affected.

The effect on the power output caused by the presence of a dam on the Tennessee River some distance below the mouth of Little Tennessee River with pool extending to the foot of the proposed Coulter Shoals Dam, would be a reduction in head during ordinary stages of about 2 feet. During high stages there would be no appreciable reduction in head, and at very low stages a decided gain would be experienced by reason of not having to pass a continuous flow into the lower pool for navigation purposes. This will make it possible to use the flashboard pondage to the fullest possible extent. No computation has been made of the amount of power that may be so gained, but obviously, whatever its amount, the benefit derived would be in the shape of primary power, and therefore valuable.

Load factor.—It is expected that a high annual load factor will be obtained at the Coulter Shoals plant. This would appear from the following considerations: (a) That the proposed power plant will be operated as a unit in an interconnected system of hydro and steam plants, and will enjoy all the advantages that ordinarily accrue from the convenient interchange of power which such a system makes possible; (b) that the plant will in time receive the benefit from the release of stored water from the reservoirs which will form part of the hydroelectric development of the upper tributaries of the Tennessee River; (c) that a large part of the load will be used for electrochemical processes requiring large blocks of power at high load factors.

In support of the reasonableness of these considerations it may be stated that the advantages to be derived from interconnection are now so generally accepted as to make the assumption here regarding it mandatory. Moreover, a number of interconnected plants are now in operation in this section of the Tennessee River Basin, and it is reasonable to suppose that their number will continue to grow and tend to the ultimate formation of a system of the superpower type, in which the Coulter Shoals plant would figure as a logical unit. Considerations (b) and (c) are fundamental of the conception of this entire investigation. That is, it is held that the maximum realization of benefits from water power development in the Tennessee Basin is predicated on the building of high head hydroelectric plants equipped with ample storage on the larger tributaries to offset the power shortage during the low water months at the main river plants; also, that in the matter of power market, electrochemical processes must be looked to for absorbing a large part of the electrical energy to be created.

As an example of the practical working out of such a plan may be cited the case of the Chattanooga & Tennessee River Power Co. which operates the Hales Bar power plant on the Tennessee River. This is a "run-of-river" plant with an installed capacity of 46,330 kilowatts and is without storage facilities except for a small amount of pondage obtained with flashboards. It is interconnected with high head plants equipped with storage reservoirs operated by the Tennessee Power Co. The Hales Bar plant is reported to have an annual load factor in the neighborhood of 85 per cent, while its daily load factor runs as high as 88 and 89 per cent. This is of the more interest here since the Hales Bar plant has many points in common with the proposed Coulter Shoals installation, but on account of certain limitations in its design, which in more than one respect has become antiquated, can be operated at high efficiencies only part of the time. The fluctuations in its head are large, and this feature alone places it at a disadvantage alongside of the proposed Coulter Shoals plant.

From the foregoing considerations it has been deemed conservative to adopt annual load factors in these estimates of 70 per cent for primary and 50 per cent for secondary power as applying to the Coulter Shoals plant after the first few years of its operation. It is believed that these load factors, in the future, will increase materially as the benefits are reaped from the release of stored water from plants on the tributaries, and also as the interconnected power net in this region becomes more highly developed. It should be remembered that the load factors here adopted are applicable only to operating conditions for plant fully loaded. How rapidly loading would progress is conjectural. It is certain, however, from experience elsewhere, that a new plant can be loaded in a shorter time when it is in an interconnected system than when it is isolated.

Backwater curve.—Depths of water on crest of dam were computed for various discharges by assuming a length of unobstructed fixed crest of 1,200 feet, and a coeffi-

cient C in the weir formula $Q=CLH^{3/2}$ ranging from 3.0 for very small discharges to 3.6 for flood discharges. These values are smaller than those given by Prof. Mansfield Merriman in his *Treatise on Hydraulics* (table on p. 166 of tenth edition), or as derived from computations made in this office for the Hales Bar Dam crest. The latter indicate a range of coefficient of 3.5 to 3.8 for depths on crest of 6 feet to 16 feet. The water-surface elevations obtained by the above method are therefore slightly in excess of what would actually be the case, and err on the side of safety as regards overflow of lands.

The elevations of the water surface at points upstream from the Coulter Shoals Dam were not computed by any empirical formula, but a backwater curve was constructed by reference to actually observed elevations of the water surface above the Hales Bar Dam. This was made possible because this dam also happens to have a length of crest of 1,200 feet, and because the river channel above it presents many analogies to that above Coulter Shoals. For this purpose the flood of March 7, 1917, was selected, the peak discharge of which according to the Chattanooga gauge reading of 47.7 feet was 313,000 cubic feet per second, and which is comparable with the maximum flood on the upper Tennessee River in the neighborhood of Coulter Shoals. The latter occurred in March, 1867, causing a stage of 45.1 feet on the Knoxville gauge, and according to the United States Geological Survey rating curve discharged 259,000 cubic feet per second at Knoxville, or 277,000 cubic feet per second at the shoals figuring the flood run-off in proportion to size of drainage areas. From existing high-water marks the following profile of 1917 flood above Hales Bar Dam was obtained.

Locality.	Water surface elevations above mean sea level.	Rise in feet.	Slope in feet per mile.
Hales Bar Dam.....	642.64		
8 miles above dam.....	645.15	2.5	0.31
10 miles above dam.....	645.95	0.8	0.40
12 miles above dam.....	647.20	1.3	0.66
14 miles above dam.....	648.65	1.45	0.72

The profile beyond the 14-mile point was not given consideration because the river channel there ceases to be comparable with that above Coulter Shoals. Assuming a crest elevation at Coulter Shoals Dam of 799 feet, then for a discharge of 277,000 cubic feet per second with a coefficient of 3.6, the elevation of the water surface at the dam was found to be 815 feet. Applying the Hales Bar profile beyond this point the following elevations were obtained:

Water surface elevations above mean sea level.

Locality:	
Coulter Shoals Dam (Mile 44).....	815.0
Mile 36.....	817.5
Concord Landing (Mile 35).....	817.9
Mile 34.....	818.3
Mile 32.....	819.6
Mile 30.....	821.0

The information at present available would not warrant extending the profile by this process any farther up the river. It is to be noted that the backwater curve, so far as obtained, is well on the side of safety, providing as it does for a discharge of 313,000 cubic feet per second, whereas the maximum recorded flood on the upper river was less than this amount by more than 10 per cent. For present purposes this backwater curve has been ample. When this investigation progresses, however, to the point where land damages are to be determined for individual pieces of property, more accurate information will be required and backwater curves for various rates of discharge will have to be computed in detail.

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